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Canada Centre for
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Centre canadien de la
technologie des
minéraux et de l'énergie

**Mining
Research
Laboratories**

**Laboratoires
de recherche
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NOISE AND VIBRATION IN MINES
RESEARCH REPORTS 1972-1986

edited by G. Knight ***traduit par N.R Billette***

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NOISE AND VIBRATION IN MINES RESEARCH REPORTS: 1972-1986.
VOLUME 1—NOISE MEASUREMENT

BRUIT ET VIBRATION DANS MINES RAPPORTS DE RECHERCHE
MESURE DE BRUIT

Edited by G. KNIGHT
Canadian Mine Technology Laboratory

Traduit par N.R. Billette
Laboratoire canadien de technologie minière

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FOREWORD

The compendium of CANMET reports on noise measurement equipment, noise assessments in mines and hearing protection assessments is a tribute to the dedication, hard work and professional expertise of Mr Savich in his field of research specialization. The research contained within the reports was accomplished by Mr. Savich or under his direction in the relatively brief period of 1972 to 1986 while working as a research scientist at the Elliot Lake Laboratory.

It is hoped that this compendium of reports on research carried out while at CANMET will be useful to those interested in finding solutions to the problems caused by miner exposure to noise and vibration.

J.E. Udd
Director
Mining Research Laboratories

AVANT-PROPOS

Le recueil de rapports de CANMET sur les instruments de mesure du bruit, les évaluations du bruit dans les mines et la protection de l'ouïe constitue un hommage à l'assiduité, le professionnalisme et l'expertise de M. Savich dans son champ de spécialisation en recherche. La recherche relatée dans ces divers rapports fut accomplie par M. Savich lui-même, ou sous sa direction, au cours de la courte période allant de 1972 à 1986, alors qu'il oeuvrait en tant que chercheur scientifique au laboratoire d'Elliot Lake.

Les Laboratoires de recherche minière de CANMET espèrent que ce recueil de rapports de recherche serviront à tous les intervenants du milieu intéressés aux problèmes reliés à l'exposition des mineurs au bruit et aux vibrations.

Directeur
Laboratoires de recherche minière
J.E. Udd

NOISE AND VIBRATION IN MINES — RESEARCH REPORTS: CANMET/ MINING RESEARCH LABORATORIES, 1972-1986.

Reprinted in 6 Volumes

Edited by

G. Knight*

French translations by

N.R. Billette*

ABSTRACT

This compendium is a reprint of all the reports on noise and vibration research undertaken by CANMET. Most of the studies were undertaken in cooperation with mines across Canada, mainly mines located in Ontario and on several occasions with the Mines Accident Prevention Association of Ontario. Two studies were carried out through the awarding of contracts.

The compendium is in 6 volumes, two of which are in parts, as follows;

1. Vol. 1–Glossary, Introduction, and Measurement Methods.
2. Vol. 2–Hearing Protection—Ear Muffs.
3. Vol. 3–Mine Noise Surveys–Part A.
4. Vol. 3–Mine Noise Surveys–Part B.
5. Vol. 3–Mine Noise Surveys–Part C.
6. Vol. 4–Mill and Surface Plant Noise Surveys–Part A.
7. Vol. 4–Mill and Surface Plant Noise Surveys–Part B.
8. Vol. 5–Noise Abatement Studies.
9. Vol. 6–Vibration Studies and General(includes unclassified)

Within each volume or section the reports are listed chronologically. The glossary has been removed from 3 of the reports and listed separately at the front. The introduction describes the main features of the contained studies in each volume.

KEYWORDS: Noise, vibration, mine surveys, noise control,
hearing protection, bibliography.

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BRUIT ET VIBRATION DANS LES MINES - RAPPORTS DE RECHERCHE: LABORATOIRES DE RECHERCHE MINIÈRE DU CANMET, 1972-1986.

Réimpression (en anglais) dans 6 Volumes

édité par
G. Knight*

traduit par
N.R. Billette*

RÉSUMÉ

Ce recueil constitue une réimpression de tous les rapports concernant la recherche sur le bruit et les vibrations exécutée à CANMET. La plupart des travaux ont été entrepris en collaboration avec des mines canadiennes, principalement avec des mines situées en Ontario et, en de nombreuses occasions, avec l'assistance de l'Association de prévention des accidents miniers en Ontario (MAPAO). Deux recherches furent réalisées en tant que contrats.

Le recueil comprend 6 volumes, dont deux comprenant plus d'une partie, répartis comme ceci:

1. Vol. 1–Glossaire, introduction et techniques de mesure.
2. Vol. 2–Protection de l'ouïe - protecteurs supra-auriculaires.
3. Vol. 3–Relevés de bruits de mines–partie A.
4. Vol. 3–Relevés de bruits de mines–partie B.
5. Vol. 3–Relevés de bruits de mines–partie C.
6. Vol. 4–Relevés de bruits d'usines et d'ateliers de surface–partie A.
7. Vol. 4–Relevés de bruits d'usines et d'ateliers de surface–partie B.
8. Vol. 5–Études de réduction du bruit.
9. Vol. 6–Études des vibrations et divers.

Dans chaque volume ou section, les rapports sont classés en ordre chronologique. Le glossaire (en anglais seulement) provient de l'amalgamation de termes contenus dans trois des rapports et a été regroupé séparément au début. L'introduction décrit les principaux éléments des travaux contenus dans chaque volume.

MOTS-CLÉS: bruit, vibration, relevé en mine, contrôle du bruit, protection auriculaire, bibliographie.

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GLOSSARY

For convenience, definitions of terms which are used in the report are assembled here. Many definitions were taken from documents prepared by ISO, ANSI and listed references.

A

A-weighting network: SeeWeighting Network.

Absorbents, Sound: Materials that absorb sound readily. These are usually construction materials designed specifically for the purpose of absorbing acoustic energy.

Accuracy: The relationship of the measured value to the actual value.

Acoustics: The science of sound, including its production, transmission and effects.

Adapters: Effective barrier for people wearing glasses in conjunction with hearing protectors. They can be worn with any muff-type hearing protector.

Ambient Noise: See Background Noise.

Anechoic Room: An enclosure whose boundaries absorb effectively all the sound. Also called free-field room or dead room.

ANSI: The American National Standards Institute.

Attenuation, Sound: The reduction, expressed in decibels, of the sound intensity.

Auricle (pinna): The outer ear, including the opening to the ear canal.

B

B-Weighting Network: See Weighting Network.

Background Noise; Background noise is the total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal.

Band-Centre Frequency: The designated (geometric) mean frequency of a band of noise or other signal. For example, 1000 Hz is the band centre frequency for the third-octave band that extends from 891 to 1123 Hz.

Bar: See Microbar.

Bel: A unit of sound level when the base of the logarithm is 10. See also Decibel.

Bizygomatic Diameter (D): Maximum distance between the bony structures (zygomatic arches) forward of the ears.

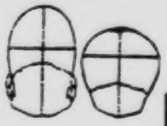
Brachycephalic Head: Cee Cephalic Index.

Bone Conduction: The process by which sound is conducted to the inner ear through the cranial bones.

C

C-Weighting Network: See Weighting Network.

Cephalic Index:



Dotted lines in the brachycephalic (right) and dolichocephalic (left) skulls indicate measurements taken.

No.	Head	Cephalic Index
1	Dolichocephalic	<75
2	Mezzocephalic	75 - 80
3	Brachycephalic	>80

Clamping Force, (Head force): The force exerted by ear muffs on the skin.

Cycle: A cycle is the complete sequence of values of a periodic quantity that occur during a period.

Cycle per second (Hz): A unit of frequency in hertz.

D

Data Analysis: The analysis of environmental data, usually in reduced form, for some intended purpose, such as prescription of design criteria or test environments or estimation of the degree of environmental hazard in a new situation.

Data Measurement: A measurement of the environment, not necessarily as part of an orderly or extensive plan, that provides either raw data or results of simple data reduction.

Data Reduction: The processing of data so as to present it in more useful form and focus on the more important aspects for an intended purpose.

Decibel (dB): A non-dimensional unit used to express sound levels. The decibel is a unit of level which denotes the magnitude of a quantity with respect to an arbitrarily established reference value of the quantity, in terms of the logarithm (to the base 10) of the ratio of the quantities:

$$dB = 10 \log_{10} \left(\frac{p}{p_o} \right)^2$$

(See Appendix A-3)

where: p is the efective, root mean square sound pressure, and p_o

is the reference pressure for airborne sound 2 x 10^{-6} N/m^2 or 20μ Pa. Decibel values will be used and tabulated according to their measurement procedures or spectrum characteristics.

NOTE:
The average $\overline{SPL}$ (sound pressure level) is calculated by the following equation:

$$SPL = 10 \log \frac{1}{n} \text{ antilog } \frac{SPL_1}{10} + \text{ antilog } \frac{SPL_2}{10} + \dots \text{ antilog } \frac{SPL_n}{10}$$

The calculation can be simplified if the maximum variation in levels is small. When the variation is 5 dB or less, the average of the levels can be found by averaging them arithmetically. If the maximum variation is between 5 and 10 dB, the average can be calculated by taking the arithmetic average and adding 1 dB.

Decibel Characteristics

Decibel Specification	Characteristics
dBA*	A-Weighting scale used.
dB (Pure)	Pure tone pressure level.
dB (Octave)	Octave band widths used.
dB (Overall)	Overall pressure level, no weighting used.
dB (Spectrum)	Spectrum level based on one hertz bandwidths.

* A sound level reading in decibels made on the A-weighted network of a sound level meter.

Diffuse Sound Field: A field in which the time average of the mean square sound pressure is everywhere the same and the flow of energy in all directions is equally probable.

Distortion:

a) Any change in the transmitted sound which alters the character of the energy- frequency distribution within the signal so that the sound being received is not a faithful replica of the source sound.

b) Distortion is an undesired change in wave form. Noise and certain desired changes in wave form, such as those resulting from modulation or detection, are not usually classed as distortion.

Dolichocephalic Head: (See Cephalic Index).

Dynamic Range: That region of measurement of an instrument or system between the noise floor and maximum permissible distortion point.

E

Ear Protector: A device worn to reduce the passage of ambient noise into the auditory system. Ear plugs are inserted in the external ear canal. Ear muffs fit over the entire ear and snug against the head.

Efficiency: The efficiency of a device with respect to a physical quantity is the ratio of the useful output of the quantity to its total input.

Environment: The surrounding conditions generated as a result of the operation of a structure or equipment.

EPA: The Environmental Protection Agency, U.S.A.

F

Filter: A device for separating components of a signal on the basis of their frequency.

Frequency: The frequency of a function periodic in time is the reciprocal of the period. The unit is the cycle per unit time and must be specified; the unit cycle per second is called hertz (Hz).

F-Test: The variance ratio test of the two samples.

H

Head Force: See Clamping Force.

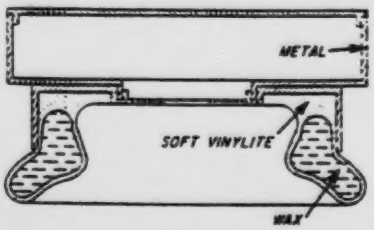
Head Band Force: See Clamping Force.

Hearing: The subjective response to sound and the nervous and cerebral operations which translate the physical stimuli into meaningful signals.

Hearing Loss: An increase in the threshold of audibility, at specific frequencies, as the result of normal aging, disease, or injury to the hearing organs. It is the symptom of reduced auditory sensitivity, synonymous with auditory impairment, when a specific cause can be ascribed. Also used, in a general sense, to describe the process of losing auditory sensitivity. Types of hearing loss are as follows:

a) Conductive: A hearing loss originating in the conductive mechanism of the ear;
b) Sensori-neural: A hearing loss originating in the cochlea or fibres of the auditory nerve. (Formerly called Perceptive Deafness).
c) Noise Induced: A sensori-neural hearing loss attributable to the effects of noise.

Helmholtz Resonator: Experimental ear muff HZM-9-B consisting of the earphone socket CZW-7 and a 50 cu cm Helmholtz resonator (J. Zwislocki). A Helmholtz resonator is a vessel containing a volume of air that is connected to a noise source. When a pure-tone sound wave is propagated along the conduit, sound wave cancellation can be obtained, thereby reducing the tone.



Hertz (Hz): Synonymous term for cycles per second. Most standardizing agencies have adopted hertz as the preferred unit of frequency.

I

IEC (ISO): International Electrotechnical Commission (International Organization for Standardization).

Impact: A collision of one mass in motion with a second mass, which may be either in motion or at rest.

Impact Noise:

a) The noise resulting from the collision of two masses.
b) A sudden sound, resulting from two surfaces striking each other, characterized by high intensity, abrupt onset, rapid decay, and often rapidly changing spectral composition.

Impulse Noise: Impulse noises are usually considered to be singular noise pulses, each less than 1 second duration, or repetitive noise pulses occurring at greater than 1 second intervals. Also defined as a change of sound pressure of 40 dB or more within 0.5 second.

ISO: The International Standards Organization.

Isolation: Isolation is a reduction in the capacity of a system to respond to an excitation, attained by the use of a resilient support.

Isolation, Sound: Materials or constructions which resist the passage of sound.

K

Kilohertz (kHz): 1000 Hz.

L

Leaks, Sound: Any opening which permits airborne sound transmission.

Logarithm: The logarithm of a number is the exponent or that power of a number to which another number, the base, must be raised to yield the number first named.

In symbols: $10^y = x$ $\log_{10} x = y$

M

Mastoiditis: An inflamation of the skull bone behind the ear.

Mean: The mean is a value such that the sum of deviations of observations from it is zero; it is thus the sum of the observations divided by their number:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

where x_i is an observation or measurement, n the total number of observations, and $\overline{x}$ the mean.

Mezzocephalic Head: See Cephalic index.

Microbar, dyne per square centimeter: A microbar is a unit of pressure commonly used in acoustics. One microbar is equal to 1 dyne per square centimeter. = 0.1 [illegible]

N

N (newton): The base unit of force, mkg s^{-2}.

Narrow Band: Applies to a narrow band of transmitted waves, with neither of the critical or cutoff frequencies of the filter being zero or infinite.

NIOSH: The National Institute for Occupational Safety and Health. USA

Noise: Noise is any undesired signal. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device.

Noise Exposure: A generic term signifying the total acoustic stimulus applied to the ear over a period of time.

Noise Reduction Rating: A decrease of the sound pressure level at a specified observation point. Noise reduction is also used to designate the differences in sound pressure levels existing at two different locations at a single time, when the designated structures are in position. The method involves calculating the noise reduction that would be achieved by the use of the treatment as measured on an A-weighted sound level meter.

NRC: The National Research Council, Ottawa.

O

Octave: The interval between two sounds having a basic frequency ratio of two.

Octave Band: A division of the audible range of frequencies into sub-groups such that in each division the upper frequency limit is twice the lower limit. The centre frequencies used to designate the octaves are twice the centre frequency of the preceding octave band. One-third octave bands: a split of an octave band into three equal parts for more detailed analysis of distribution of sound energy.

Octave Band Analyzer: A device for measuring pressure levels of a sound for a frequency band corresponding to a specific octave.

Octave-Band Spectrum: See Spectrum.

Operator's Normal Position: The location of an operator with respect to a machine during the time it is operating. The position should be recorded for the particular machine installation.

Oscillation: The variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the reference.

OSHA: The Occupational Safety and Health Act (U.S.A.).

Organ of Corti: An aggregation of nerve cells lying on the basilar membrane which senses vibrations that are transmitted to the brain, where they are interpreted as sound.

Pa (pascal): The base unit of pressure (Pa = N/m^2).

Period: The time required to complete one cycle; it is the reciprocal of the frequency.

Physical Method: A method using apparatus for measuring attenuation and the cushion efficiency of ear muffs.

Pistonphone: A small chamber equipped with a reciprocating piston of measurable displacement that permits the establishment of a known sound pressure in the chamber.

Pressure Spectrum Level: The pressure spectrum level of a sound at a specified frequency is the effective sound pressure level for the sound energy contained within a band 1 Hz wide, centred at the specified frequency. Ordinarily this has significance only for sound having a continuous distribution of energy within the frequency range under consideration. The reference pressure should be explicitly stated.

Psychophysical Method: A method using human head for measuring attenuation of ear muffs.

Pure Tone: A sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of the time. Audibly, it is characterized by a singleness of pitch.

R

Random Noise: An oscillation whose instantaneous magnitude is not specified for any given instant of time. The instantaneous magnitude of a random noise is specified only by probability distribution functions giving the fraction of the total time that the magnitude, or some sequence of magnitudes, lies within a specified range.

Random Noise Generator: The noise generator produces a noise signal with uniform spectrum density in the frequency range 20 - 20,000 Hz with true (normal) Gaussian amplitude distribution.

Raw Data: Essentially, complete data in the time domain for a particular measurement without data reduction to de-emphasize unimportant or redundant detail or to provide a more useful mode of presentation.

Real-Ear Attenuation: The mean value (in decibels) of the occluded threshold (hearing protector in place) of audibility minus the open threshold of audibility (ears open and uncovered) for all listeners on all trials under otherwise identical test conditions.

Receiver: The affected person or equipment.

Reflection: The return from surfaces of sound energy not absorbed upon contact with the surfaces.

Reverberation: The persistence of sound in an enclosed space, as a result of multiple reflections after the sound source has stopped.

Reverberation Chamber: An enclosure in which all the surfaces have been made as sound reflective as possible. Reverberation chambers are used for certain acoustical measurements.

R.M.S.: Root mean square.

S

Sensitivity: The sensitivity of a receiving transducer is the ratio of its electrical output to its mechanical input.

Signal: A signal is a disturbance used to convey information.

Slow Response: A selectable mode of operation of a sound level meter or analyzer in which the indicator has high damping and therefore slowly responds to change in sound level. This mode tends to provide an average reading.

Sound: The auditory sensation produced through the organs of hearing, usually by vibrations transmitted in a material medium, commonly air.

Sound Absorption: The change of sound energy into some other form, usually heat, in passing through a medium or on striking a surface. In addition, sound absorption is the property possessed by materials and objects, including air, of absorbing sound energy. See aldo Attenuation.

Sound Insulation: The degree by which sound transmission is reduced by means of sound insulating structures and materials.

Sound Level: A-weighted value of sound pressure level as determined with a sound level meter.

Sound Level Meter: A device to measure sound level or weighted sound level, constructed in accordance with the standard specifications for sound level meters set up by the American National Standards Institute (ANSI). The sound level meter consists of a microphone, an amplifier to raise the microphone output to useful levels, a calibrated attenuator to adjust the amplification to values appropriate to the sound levels being measured, and an instrument to indicate the measured sound level; optional weighting networks are included to adjust the overall frequency characteristic of the response.

Sound Pressure Level (SPL): The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure shall be explicitly stated. The following referenced pressures are in common use: (a) 0.0002 microbar, or (b) 1 microbar. Reference pressure (a) is in general use for measurements concerned with hearing and with sound in air, while (b) has gained widespread acceptance for calibration of transducers and various kinds of sound measurements in liquids.

Spectrum: Spectrum is used to signify a continuous range of components, usually wide in extent, within which waves have some specified common characteristics; for example, audiofrequency spectrum.
Octave-band spectrum: The ensemble of octave-band pressure levels comprising a sound. The audible spectrum is conventionally taken to embrace eight octaves. See also Octave-band.
1/3 Octave-band spectrum: The ensemble of band-pressure levels in bands 1/3 octave wide comprising a sound.

Spectrum Level: The spectrum level of a specified signal at a particular frequency is the level of that part of the signal contained within a band 1 Hz wide, centred at the particular frequency. Ordinarily this has significance only for a signal having a continuous distribution of components within the frequency range under consideration. The words "spectrum level" cannot be used alone, but must appear in combination with a prefatory modifier, such as pressure, velocity, voltage.

Standard Deviation: A numerical indication of the scatter of values of a variable around their mean (symbol σ). Specifically, it is the square root of the mean squared deviation, given by:

$$\sigma = \sqrt{\frac{\Sigma d^2}{n - 1}}$$

where d is the difference between the grand mean and an individual observation and n is the number of observations. In a normal distribution, a range of two standard deviations on each side of the mean will include 95.45 percent of all values, and three standard deviations on each side of the mean, 99.73 percent.
When the standard deviation is determined from a sample of values and not from the parent population (which is frequently unknown), the denominator within the square root should be taken in n - 1, due to the fact that one degree of freedom out of the total n is used to estimate the mean value x.

Standard Error: Standard error of the mean of a sample. The standard error is found by dividing the standard deviation of the items in the sample by the square root of their number. The mean of the population from which the sample was obtained is not likely to differ from the sample mean by more than plus or minus twice the standard error.

T

Temporary Threshold Shift (TTS): The component of threshold shift which shows progressive reduction with the passage of time when the apparent cause has been removed. The temporary hearing loss suffered as the result of noise exposure, if all or part of the loss is recovered during an arbitrary period of time when one is no longer subjected to the noise.

Tone: a) A sound wave capable of exciting an auditory sensation having pitch.
b) A sound sensation having pitch. See Pure Tone.

Transmission: The propagation of a vibration through various media.

Transmission Loss:

a) The difference between the noise level outside the ear muff and inside the ear muff.

b) The ratio, expressed in decibels, of the sound energy incident on a structure to the sound energy which is transmitted. The term is applied both to building structures (walls, floors, etc.) and to air passages (muff, muffler, ducts, etc.).
Transmission loss is the reduction in the magnitude of some characteristic of a signal, between two stated points in a transmission system. The characteristic is often some kind of level, such as power level; in acoustics the characteristic that is commonly measured is sound pressure level. Thus, if the levels are expressed in decibels, the transmission level loss is likewise in decibels.

W

Wave: A disturbance which is propagated in a medium in such a manner that at any point in the medium, the quantity serving as measure of disturbance is a function of the time, while at any instant the displacement at a point is a function of the point. Any physical quantity that has the same relationship to some independent variable (usually time) that a propagated disturbance has, at a particular instant with respect to space, may be called a wave.

Weighting Network: An electrical network designed to be incorporated in a sound level meter such that the latter conforms to a specified weighting curve. The three networks are designated A, B, and C, according to ANSI S 1.4 - 1971.

INTRODUCTION

This research was undertaken because noise-induced hearing loss is a substantial problem in the mining industry and because vibration-induced damage occurs to blood capillaries in the hands of miners, particularly drillers. Noise-induced hearing loss generally occurs over a long period of time. Because humans are adaptable and tend to compensate for the gradual loss, the impairment goes unrecognized for a long time. Exposure to very loud noises, such as explosions, can give rise to immediate and disabling damage to the hearing system.

Hearing impairment affects both employees and employers. Compensation payments are becoming substantial. The hearing loss can only be detected in the early stages by frequent checks of hearing acuity and this is now required for miners in most Canadian jurisdictions.

Noise is measured as the peak to trough pressure difference in the vibration waves in air. The results are expressed in relative terms to the hearing sensitivity of (young adult) humans in good health using a logarithmic scale to the base 10. Thus, an increase of one Bel is equivalent to a ten times stronger noise level. However, the Bel is a large unit and it is more convenient to use a unit ten times smaller, the decibel. Hearing acuity is frequency dependent. It peaks at a frequency of about 1 000 Hertz (cycles per second) and falls off to the extreme limits, roughly 20 and 20 000 Hz. Sound measurement equipment is much less frequency dependent and a weighting factor is used to relate it to human hearing. The "A"-scale is used in hearing loss programs generally. Thus, the weighted noise level in decibels is usually abbreviated as dBA. Hearing loss is believed to occur when exposure is above a threshold level, 85 dBA and 90 dBA have been specified in various jurisdictions. The hearing loss is proportional to the height of the noise excursion and its duration. Three factors are in use for equating the potential hearing loss to the noise level:

1. A doubling every 3 dBA–The equal energy principle, used in many hearing loss control recommendations.
2. A doubling every 4 dBA–used in one or more recommendations.
3. A doubling every 5 dBA–used in the principal USA legislation: the Occupational Safety and Health Act (OSHA).

Canadian regulations are set provincially and federally: either factor 1 or 3 is used.

In addition to potential hearing losses high noise levels lead to problems in safety, fatigue and communication.

Most of the noise studies have been directed at surveys of noise in mines and the efficacy of hearing protection measures. The mine surveys have shown that many miners are exposed to noise levels above the threshhold for potential hearing loss and that immediate hearing protection is required as well as an effort to reduce the noise level of mining machinery.

This compendium is a reprint of all the reports on noise and vibration research undertaken by CANMET. Most of the studies were undertaken in cooperation with mines across Canada, mainly mines located in Ontario and, on several occasions, with the Mines Accident Prevention Association of Ontario. Two studies were carried out through the awarding of contracts. A few of the early reports by Miron Savich were based on his MSc. thesis work undertaken at the Institute of Mineral Research of McGill University, situated at Mont St. Hilaire, Quebec.

The compendium is in 6 volumes, two of which are in parts, as follows;

1. Vol. 1–Glossary, Introduction, Measurement methods.
2. Vol. 2–Hearing Protection—Ear Muffs.
3. Vol. 3–Mine Noise Surveys–Part A.
4. Vol. 3–Mine Noise Surveys–Part B.
5. Vol. 3–Mine Noise Surveys–Part C.
6. Vol. 4–Mill and Surface Plant Noise Surveys–Part A.
7. Vol. 4–Mill and Surface Plant Noise Surveys–Part B.
8. Vol. 5–Noise Abatement Studies.
9. Vol. 6–Vibration Studies and General(includes unclassified)

Within each volume or section the reports are listed chronologically. The glossary has been removed from 3 of the reports and amalgamated. It is presented separately at the front, following the contents table.

The noise measurement methods used are described in some reports in the first volume as well as being described in many of the other reports on surveys etc.. Five main classes of noise measurement techniques have been used in the noise surveys. These are:

1. Hand-held meters with "A"-scale weighting and slow response time averaging over a short period of time, a second or less, with manual recording. This was used in the earlier surveys and occasionally later. A graphical method of determining the average noise level for the survey is given in report 75–71.
2. The hand-held sound level meter was also used in the peak measurement mode for studies of impulse, or short duration, noise as in report 84–83.

3. A shift length recording system in which the average noise level over a period, such as a minute, is stored on a memory bank and read out later. In the system used, the results were read at the end of the shift and analysed using a computer program as described in report 78–62.

4. The noise dosimeter averages noise level over a short period of time and, if it exceeds the threshhold, adds it up using an appropriate factor to give the noise level as a ratio of the exceedance to permissible for the shift. The instrument usually has an indicator for showing whether the noise level has exceeded the ceiling level of 115dBA promulgated in the OSHA regulations (presumably intended for unprotected ears). This instrument has been used in many surveys and tests on hearing protectors. One unit was described and tested in report 76–83.

5. Frequency analysis sound level meter. This determines the sound level in each band of frequency of significance, usually one third octave wide. The equipment is desirable because the attenuation of noise by any barrier is frequency dependent and because the frequency of an offensive sound may be very helpful in determining its source. Ear muffs are sound attenuators and therefore frequency dependent, they are not as good attenuators at low frequencies as at high frequencies.

Ear muffs (hearing protectors) were shown to be highly efficient in laboratory tests providing attenuations of 31 to 44 dBA at frequencies of 1 000 Hz and above. Safety glass-frames passing under the seal of the ear muff, however, were found to reduce attenuations to 25 to 34 dBA. The wearing of safety glasses is obligatory in most working places in the mining industry. Field studies in mines showed that the effective protection factors for ear muffs could be less than 10 dBA. The surveys carried out at Falconbridge Mines Ltd., Reports 86–58, 86–59, 86–60, 86–61 with a final summary in 86–88 illustrate the value of such studies. The attenuations of ear muffs found in mines are shown in Figure 1, where the measured attenuation(OSHA basis) in dBA is shown plotted against the mean sound level in dBA (variously described in the reports as $L_{eq}(60s)$; L_{OSHA} or $L_{Avg.}$). The required attenuation line is drawn assuming that the average sound levels persist for a full 8 hour shift and that ear plugs are not worn. This figure suggests that about half of the population examined were not protected to the extent required. However, neither of these assumptions are true and it is probable that substantially more than the half of the population was protected to the extent required. The major reason for the poor performance of ear muffs in practise was found to be poor fitting, the spring clamping force was often inadequate, particularly on small headed individuals. Emphasis was placed on the measurement and control of clamping force and the need to fit earmuff supports to head size. On the basis of these surveys recommendations were made to improve control of hearing protection programs.

The noise surveys are a useful repository of information. The detailed surveys, using the data logging technique, which form the major part of volumes 3 and 4, provide invaluable information to those planning noise control programs in many mining operations. Nearly 700 man-days were logged in the detailed surveys. It could be seen that the distribution of noise exposure during the shift varies from nearly constant to highly variable. In the mines 262 shifts out of the 432 recorded were worked at sound levels above permissible exposure. The highest values were about 40 times greater requiring hearing protection of at least 28 dBA attenuation. This would be even higher if the proposed OSHA standards instead of the existing rules (at the time the reports were written) were used as the basis for assessment. In the mills and surface plants only 13 out of the 250 shifts recorded were worked at sound levels above permissible exposure. The highest value required about 10 dBA attenuation in the hearing protection.

Noise control studies have been carried out with respect to light and medium weight percussion rockdrills, diamond drills and diesel engine exhaust systems. The diamond drill studies point out the need for a thorough investigation of all the noise sources, four major sources have been identified. Reduction of only one source would, as a result, produce almost no effect on sound level, a reduction of about 1 dBA. It may, however, modify the sound quality significantly.

The high noise levels measured in mining emphasize the requirement for substantial work to control noise on mining machinery. It is likely that eventually it will be desirable not to expose men to sound levels over 85 dBA and that the necessity for hearing protection will be considered an undesirable working condition to be eliminated.

The contract study on vibration found that stopers and jackleg drills subjected miner's hands to vibration levels sufficient to induce vibration white finger disease in periods of one to four years in over half the population. It was also shown that vibration isolators could be effective in substantially reducing vibration transmission to hands and proposed that vibration isolation handles should be developed and used on percussion drills. Some sites where whole-body exposure to vibration exceeded guidelines were found in surface plant and mills. Underground diesel powered vehicles were not examined.

The report 73–17 in the miscellaneous section in volume 6 is a good exposition of the noise and vibration problems in mines. The topics covered include noise and vibration measurement; noise and vibration exposure standards; and noise and vibration sources; as well as control methods.

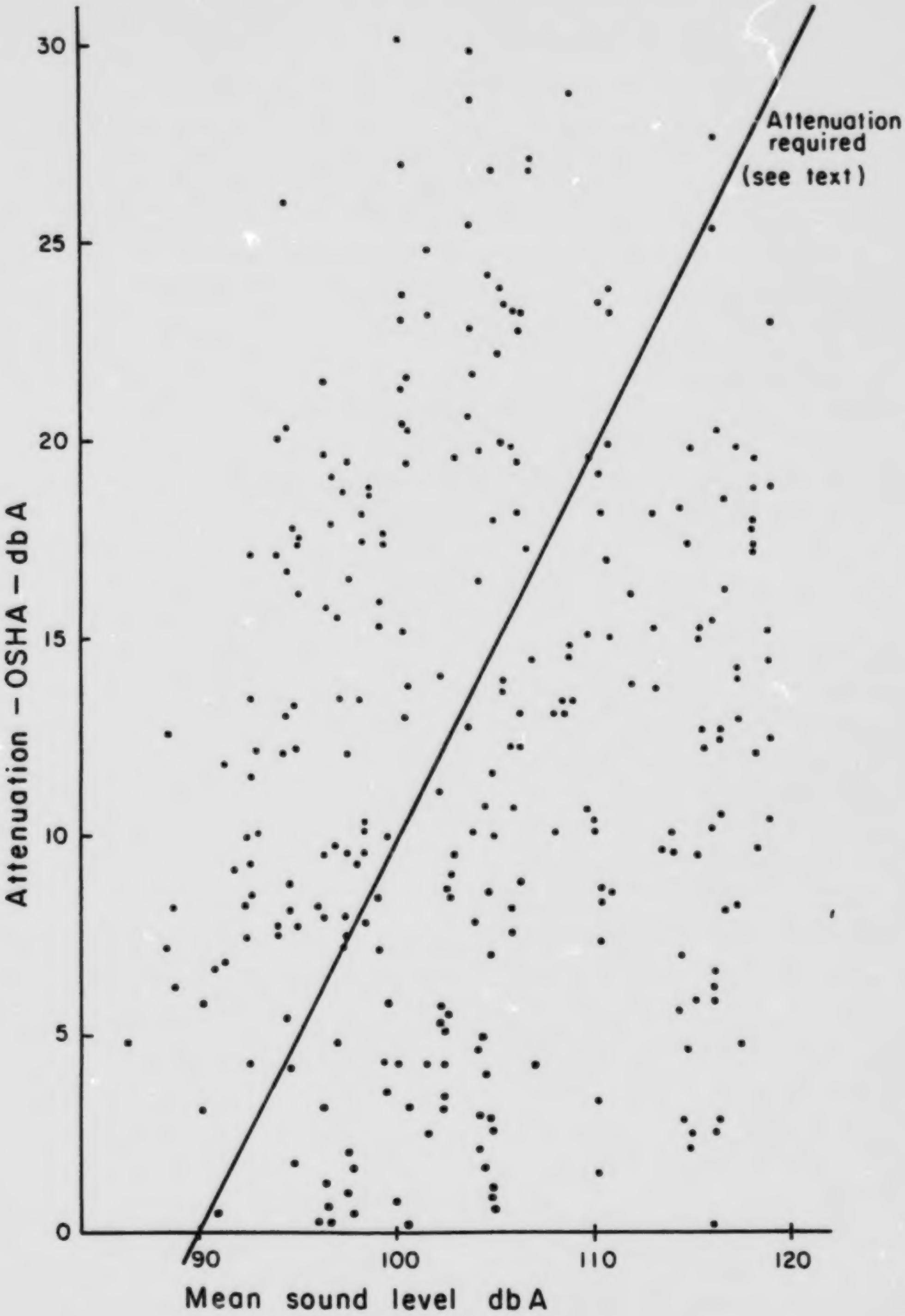


Fig. 1–The attenuation of ear muffs measured in use in mines.

Fig. 1–L'atténuation des protecteurs supra-auriculaires en usage dans le mines

It should be appreciated that many of the reports cover more than one topic and that they have not been cross-referenced. They are entered in the category corresponding to the major aspect studied.

The report pages have not been renumbered. To assist in locating each report red coloured pages are used to separate them. Each of these has page and report numbers in the top right hand corner and the full title and description of the report and its publication details, if other than a divisional report.

The reports are in their original language, usually english. The abstracts have been translated into french and are given at the front of each report.

ACKNOWLEDGEMENTS

The editor wishes to thank his colleagues in the Mining Research Laboratories for assistance in gathering and compiling these reports.

INTRODUCTION

Ces travaux de recherche ont été entrepris parce que la perte auditive due au bruit constitue un problème important dans l'industrie minière, ainsi qu'à cause des dommages aux capillaires sanguins induits par vibration aux mains des mineurs, et plus particulièrement des foreurs. La perte auditive due au bruit découle d'une exposition prolongée. Puisque les humains s'adaptent facilement et tendent à compenser la perte graduelle, la détérioration passe longtemps inaperçue. Toutefois, l'exposition à de très grands bruits, une explosion par exemple, peut entraîner un dommage immédiat incapacitant du système auditif.

La perte auditive affecte tant l'employeur que l'employé. Les paiements compensateurs sont devenus substantiels. Les premiers signes de dégradation de l'ouïe ne sont reconnus qu'au prix de multiples vérifications de l'acuité auditive, ce qui est maintenant exigé dans la plupart des juridictions canadiennes concernant les mineurs.

Le bruit est mesuré comme différence entre le sommet et le creux des ondes vibratoires dans l'air. Les résultats sont exprimés en termes relatifs à la sensitivité auditive d'un humain (jeune adulte) en bonne santé, en utilisant une échelle logarithme de base 10. Ainsi, une augmentation du niveau sonore d'un Bel équivaut à décupler l'énergie acoustique. Toutefois, le Bel constitue une unité représentant une somme énergétique importante, de sorte qu'il est plus approprié d'utiliser le décibel, une unité dix fois plus petite. L'acuité auditive dépend de la fréquence de l'onde. Elle atteint son maximum aux alentours de la fréquence de 1,000 Hertz (cycles par seconde) et diminue aux deux extrémités du spectre, soit 20 et 20,000 Hz respectivement. L'équipement de mesure du son est beaucoup moins dépendant de la fréquence utilisée, de sorte qu'un facteur de pondération est nécessaire pour relier le niveau sonore à l'acuité auditive humaine. L'échelle "A" est généralement utilisée dans les programmes de perte auditive. Dans ce cas, le niveau sonore pondéré est habituellement abrégé à dBA. La perte auditive est considérée se produire au-delà d'un seuil, 85 dBA et 90 dBA étant la norme dans diverses réglementations. La perte auditive est proportionnelle à la puissance de l'onde sonore et à la durée de l'exposition. Trois facteurs légaux sont utilisés pour établir la relation entre dommage potentiel et niveau sonore:

1. Le dommage double tous les 3 dBA – le principe d'énergie équivalente, à la base de nombreuses recommendations du contrôle de la perte auditive.
2. Le dommage double tous les 4 dBA – utilisé dans une recommendation ou plus.
3. Le dommage double tous les 5 dBA – en usage dans la principàles législation américaine, l'Acte de santé et sécurité occupationnelles (OSHA).

Les réglementations canadiennes sont émises aux niveaux provinciaux et fédéral: elles utilisent le facteur 1 ou le facteur 3.

En plus des pertes auditives potentielles, les niveaux sonores élevés entraînent des problèmes de sécurité, de fatigue et de communications.

La plupart des travaux sur le bruit ont été orientés vers des relevés du bruit dans les mines et vers l'appréciation de l'efficacité des mesures de protection de l'ouïe. Les relevés dans les mines ont démontré que plusieurs mineurs sont exposés à des niveaux sonores supérieurs au seuil de dommage auditif potentiel et qu'une protection immédiate de l'ouïe est nécessaire en parallèle à l'implantation de mesures de réduction du bruit de l'équipement et matériel minier.

Ce recueil incorpore tous les rapports de recherche sur le bruit et les vibrations réalisés par CANMET. La plupart des travaux ont été réalisés en collaboration avec des mines canadiennes, principalement avec des mines situées en Ontario et, à maintes reprises, avec l'assistance de l'Association de prévention des accidents miniers en Ontario (MAPAO). Deux recherches furent réalisées sur une base contractuelle. Quelques uns des premiers rapports de Miron Savich étaient basés sur sa thèse de maîtrise réalisée à l'Institut de Recherche minérale de l'Université McGill, situé à St-Hilaire, Québec.

Le recueil comprend six volumes, dont deux en plusieurs parties, comme suit:

1. Vol. 1–Glossaire, introduction et techniques de mesure.
2. Vol. 2–Protection de l'ouïe - protecteurs supra-auriculaires.
3. Vol. 3–Relevés de bruits de mines–partie A.
4. Vol. 3–Relevés de bruits de mines–partie B.
5. Vol. 3–Relevés de bruits de mines–partie C.
6. Vol. 4–Relevés de bruits d'usines et ateliers de surface–partie A.
7. Vol. 4–Relevés de bruits d'usines et ateliers de surface–partie B.
8. Vol. 5–Études de réduction du bruit.
9. Vol. 6–Études des vibrations et divers.

Dans chaque volume ou section, les rapports sont classés en ordre chronologique. Le glossaire (en anglais seulement) provient de l'amalgamation de termes contenus dans trois des rapports. Il est présentement à part au début, tout de suite après la table des matières.

Les techniques de mesure du bruit utilisées sont décrites dans quelques rapports du premier volume, ainsi que dans de nombreux autres reliés aux relevés de mines, usines et ateliers. Cinq classes principales de techniques de mesure du bruit ont été expériementées dans les relevés sonores. Ce sont:

1. Des appareils manuels pondérant les fréquences selon l'échelle "A", avec un temps de réponse assez lent et le calcul de la valeur moyenne sur une brève période, une seconde ou moins, et enregistrement manuel du résultat. Il s'agit de la technique utilisée lors des premiers relevés, puis occasionnellement par la suite. Une méthode graphique pour déterminer le niveau acoustique pondéré au cours du relevé est expliquée dans le rapporté 75-71.
2. Le sonomètre manuel a aussi été utilisé en mode de mesure des bruits d'impact pour des études d'impulsion, ou bruit de courte durée, comme dans le rapport 84-83.
3. Un système d'enregistrement pour la période de travail (8 heures), qui cumule le bruit moyen d'une période de courte durée, une minute par exemple, et la conserve en mémoire pour lecture ultérieure. Le système utilisé permettait la lecture de l'information à la fin de la période de travail et son traitement ultérieur informatisé, tel que décrit dans le rapport 78-62.
4. L'audio-dosimètre calcule le niveau sonore moyen sur une courte période de temps et, surtout s'il excède le niveau légal, calcule le rapport du niveau sonore obtenu au niveau permis pour la période de travail. L'instrument possède également un voyant lumineux qui indique un dépassement de la limite légale absolue de 115 dBA promulguée dans les règlements OSHA (sans aucun doute pour une ouïe sans protecteur). Cet instrument a été utilisé dans plusieurs relevés et lors de tests concernant les protecteurs auriculaires. Un tel appareil a été décrit et vérifié dans le rapport 76-83.
5. Le sonomètre d'analyse fréquentielle. Cet instrument mesure le niveau acoustique moyen dans chaque bande de fréquence significative, habituellement de la largeur d'un tiers d'octave. L'instrument est nettement recommandable, puisque l'atténuation du bruit par toute barrière est fonction de la fréquence et parce que la fréquence d'un son agresseur contribue à localiser sa source. Les protecteurs auriculaires sont des atténuateurs de son et, de ce fait, dépendent de la fréquence d'émission. Ils n'atténuent pas les basses fréquences avec autant de bonheur que les hautes fréquences.

Les protecteurs supra-auriculaires ont démontré des habiletés d'atténuation allant de 31 à 44 dBA en laboratoire pour les fréquences de 1,000 Hz et plus. Les montures de lunettes de sécurité passées sous les coussins du protecteur réduisent cependant la protection qui passe alors de 25 à 34 dBA. Comme le port de lunettes protectrices est obligatoire pour la plupart des postes de travail dans l'industrie minière, des études sur le terrain dans les mines ont démontré que la protection réelle obtenue par des protecteurs supra-auriculaires peut ne pas dépasser 10 dBA. Les relevés effectués à Falconbridge Ltée, rapports 86-58, 86-59, 86-60, 86-61 avec un résumé final dans 86-88, illustrent la validité de tels travaux. La figure 1 (voir page 5) illustre l'atténuation en dBA (base OSHA) des protecteurs supra-auriculaires en usage dans les mines, où cette dernière est comparée au niveau acoustique pondéré en dBA (décrit différemment dans les rapports comme $L_{eq}(60s)$; L_{OSHA} ou $L_{Avg.}$). La ligne d'atténuation requise est illustrée en assumant que les niveaux acoustiques moyens persistent tout au long de la période de 8 heures et que des bouchons d'oreilles ne sont pas utilisés. Cette figure suggère que la moitié de la population des mineurs n'est pas protégée au niveau légal requis. Toutefois, aucune de ces deux hypothèses n'est vraie et il est fort probable qu'une proportion largement supérieure à la moitié se trouve protégée au niveau requis. La principale raison de la faible performance des protecteurs supra-auriculaires en pratique découle d'un mauvais ajustement, la force du ressort étant souvent inadéquate, principalement chez les individus ayant un faible tour de tête. L'emphase a été mise sur la mesure et le contrôle de la force de serre et le besoin d'ajuster les supports des protecteurs au tour de tête. Des recommendations basées sur ces relevés ont donc été faites, afin d'améliorer les programmes de contrôle pour la protection de l'ouïe.

Les relevés sonores constituent un recueil d'informations. Les relevés détaillés, utilisant la technique d'enregistrement des données, constituent l'essentiel des volumes 3 et 4, et contiennent de l'information précieuse pour tous ceux qui entreprennent des programmes de contrôle du bruit dans des opérations minières. Près de 700 jours-hommes ont été enregistrés lors des relevés détaillés. Il est ainsi possible de constater que la distribution d'exposition des mineurs au bruit varie, au cours de la période de travail, de presque constante à très variable. Dans les mines, 262 des 432 périodes de travail enregistrées l'ont été à l'aide de l'audio-dosimètre en niveau relatif à l'exposition permise. Les valeurs les plus fortes indiquaient un dépassement du seuil de 40 fois, signifiant une protection de l'ouïe de l'ordre de 28 dBA d'atténuation. Cette atténuation serait encore supérieure si les nouveaux standards proposés par OSHA étaient utilisés comme base au lieu des règles actuelles (au moment où les rapports étaient rédigés). Dans les usines et ateliers de surface, seulement 13 des 250 périodes de travail enregistrées l'ont été à l'aide de l'audio-sonomètre. La valeur la plus forte requerrait une atténuation de l'ordre de 10 dBA pour assurer la protection légale de l'ouïe.

Les travaux de contrôle du bruit ont été entrepris sur des foreuses à percussion de poids léger à moyen, sur les foreuses à diamant et sur les systèmes d'échappement des moteurs diesels. Les études sur les foreuses à diamant ont démontré un besoin d'investigation approfondie de toutes les sources de bruit, quatre sources majeures ayant été identifiées. La réduction d'une seule source résulterait en une atténuation à peine discernable du niveau acoustique moyen, à savoir 1 dBA. Elle pourrait cependant modifier la qualité sonore de façon appréciable.

Les niveaux sonores élevés mesurés dans les mines mettent l'emphase sur le besoin de travaux importants, afin de réduire le bruit du matériel minier. Il est probable qu'il faudra éventuellement limiter l'exposition des travailleurs à des bruits n'excédant pas 85 dBA et que l'usage de protecteurs auriculaires devienne une condition de travail indésirable, à éliminer.

L'étude contractuelle sur les vibrations a démontré que les foreuses manuelles verticales et sur béquille exposaient le mineur à des niveaux vibratoires suffisants pour induire le phénomène de Raynaud (insensibilité de la main) chez plus de la moitié de la population sur une période allant de 1 à 4 ans. Elle a aussi permis de démontrer que les isolants vibratoires permettent de réduire la transmission des vibrations à la main et suggéré de développer des poignées isolant les vibrations et de les adapter aux foreuses à percussion. Ces relevés ont aussi identifié des sites où les vibrations corporelles excédaient les directives dans les usines et ateliers de surface. Les véhicles souterrains à moteur diesel ne furent pas examinés.

Le rapport 73-17, dans la section "divers" du volume 6 expose bien les problèmes de bruit et vibrations dans les mines. Les sujets abordés sont la mesure du bruit et des vibrations, les standards d'exposition au bruit et aux vibrations, les sources de bruit et de vibrations, et les méthodes de contrôle.

Il faut enfin mentionner que plusieurs des rapports couvrent plus d'un sujet et qu'ils n'ont pas de renvoi mutuel. Ils sont inclus dans le manuel qui correspond au principal aspect étudié.

Les pages des rapports n'ont pas été renumérotées. Pour mieux localiser chaque rapport, une page rouge est insérée au début de chacun. Chaque rapport est numéroté dans le coin supérieur droit et contient, en plus, son titre propre et la description du contenu, ainsi que son lieu d'édition lorsqu'il ne s'agit pas d'un rapport divisionnel. Un résumé français est compris avec chaque rapport.

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VOL. I Report 16

83-56 M. Savich

How CANMET tests noise pollution

1983

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Mise au point d'une chambre anéchoique

par Miron Savich*

RÉSUMÉ

L'Institute of Mineral Industry Research de St-Hilaire a construit une chambre anéchoique pour mesurer le bruit émis par des marteaux perforateurs légers et moyennement lourds. La chambre se caractérise par sa simplicité et son coût modique.

Les dimensions générales de la chambre sont les suivantes : 9 pi x 6 pi x 6 pi à l'extérieur et 6 pi x 3 pi x 3 pi à l'intérieur. Elle est garnie avec des coins en forme de dièdres en mousse Ecodamp MG (densité : 35 kg km^2). La chambre est posée sur des coussins en caoutchouc et elle est ventilée continuellement. Elle fournit une fréquence naturelle lorsque la charge est inférieure à 7 Hz. D'après nos mesures, l'isolation contre le bruit autour du bâtiment est bonne. Le matériel Brüel et Kjaer (B et K) a été utilisé pour tous les essais. Le système d'orientation du microphone, l'installation du câble de mesure et l'installation électrique sont aussi précisés.

Enfin, certaines mesures relatives à la chambre terminée, en ce qui concerne la performance en champ libre, sont décrites. D'après les mesures d'étalonnage, la fréquence de coupure est de 400 Hz. Ces mesures montrent que la chambre donne de bons résultats au-dessus de 400 Hz et dans des conditions extérieures extrêmes.

RUDARSKO-METALURŠKI ZBORNIK
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Development of an Anechoic Chamber

by Miron SAVICH*

ABSTRACT

In the Institute of Mineral Industry Research at St. Hilaire, an anechoic chamber was constructed for the measurement of noise from light and medium hammer drills. The principle features of the chamber are its simplicity and cheapness.

The general dimensions of the chamber are outside, 9 × 6 × 6 ft. and inside 6 × 3 × 3 ft. It is lined with dihedral-shaped wedges manufactured from [illegible] MG foam (density 33 kg/m³). The chamber is continuously ventilated and supported on rubber pads. It provides natural frequency under load of less than 7 Hz. The insulation against noise in the vicinity of the building is good according to our measurements. Brüel and Kjaer (B and K) equipment was used for all tests. Mention is also made of the microphone orientation system, the measurement cable installation, and the electrical installation.

Finally, some measurements on the completed chamber with regard to their free-field performances, are described. Calibration predicts cut-off frequency at 400 Hz. These measurements show that the chamber can be used for [illegible] measurements above 400 Hz and under extreme outside conditions.

1. INTRODUCTION

The anechoic chamber in the Institute for Mineral Industry Research at St. Hilaire was constructed in 1969 and 70 for the Department of Mining Engineering and Applied Geophysics, McGill University, Montreal.

The principal acoustic characteristics desired were determined during the initial research to provide a simple, economical, anechoic chamber. These principal acoustic characteristics were related mainly to the analysis of noise from pneumatic rock drills above 500 Hz, especially those pitches which are critical to understanding speech and hearing loss.

In this paper, the extensive study of the anechoic chamber is summarized with the calibration measurements. These measurements show that the anechoic chamber can be used for exacting measurements and under extreme outside conditions.

To perform these measurements, the author gave his own variant of the anechoic chamber, constructed exclusively for the measurement of noise of light and medium drill hammers under different thrust (power pressures).

Anechoic Chamber: Pneumatic Rock Drill: Noise Analysis

* Elliot Lake Laboratory, Mines Branch, Mining Research Centre, Department of Energy, Mines and Resources, Elliot Lake, Ontario.

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2. DESIGN CONSIDERATIONS

The anechoic chamber (Figure 1) was patterned after a similar room at the University of Queensland, Australia (1). The dimensions are as follows:

outside: 9 × 6 × 6 ft;
inside: 6 × 3 × 3 ft.

Inside, the chamber is lined with wedges of polyurethane ether fixed to wooden frames.

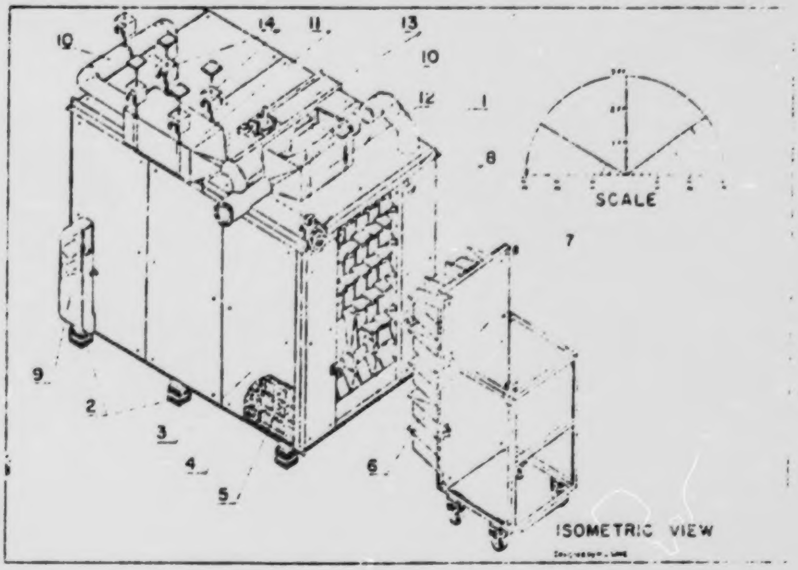

Figure 1: The Anechoic Chamber of the Institute for Mineral Industry Research at St. Hilaire (1 — Basic frame, 2 — Rubber pads, 3 — Asbestos plate, 4 — Rock wool, 5 — Wooden frame, 6 — Wedges, 7 — Door, 8 — Lock, 9 — Input silencer, 10 — Pipes, 11 — Quiet-duct silencer (exhaust), 12 — Quiet-duct silencer (ventilation), 13 — Microphone orientation system, 14 — Vibration isolation)

2.1. Isolation from Mechanical Vibrations

The anechoic chamber is supported by six rubber pads (hardness 50° Shore). Each isolation assembly consists of two pieces of rubber 6 × 6 × 1 ½ in. separated by pieces of three-ply wood 6 × 6 × 1 in. It provides natural frequency under load of less than 7 Hz (1, 2, 3).

The quiet-duct silencer and the pipe are supported by vibration-free ceiling hangers. Where the pipe passed through the walls, it was isolated by soft rubber.

In the anechoic chamber the support for the hammer drill is contained in a concrete column which is buried under the floor of the building. The sand

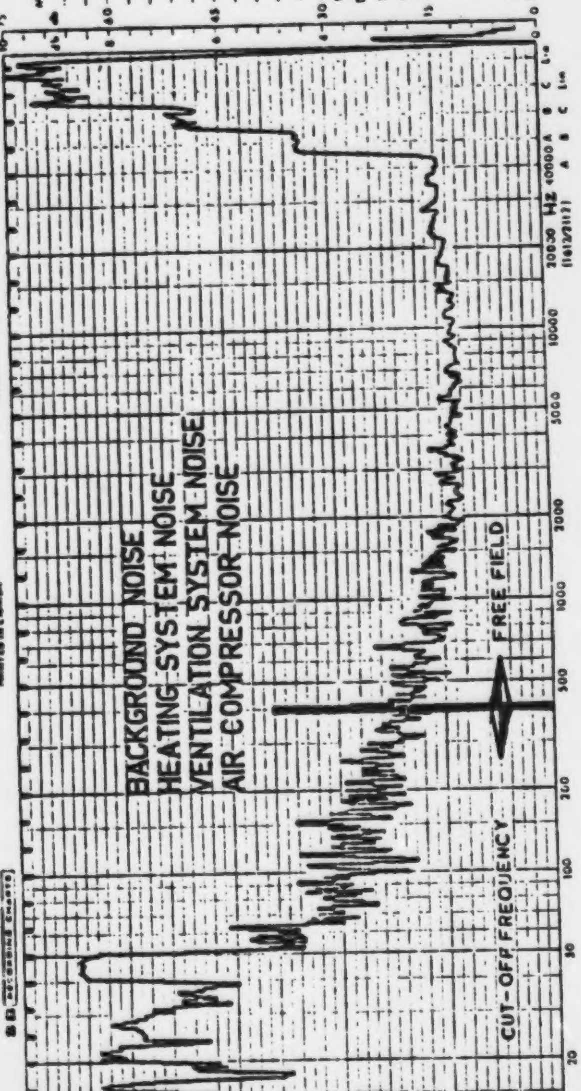

Figure 2: Recorder Spectrogram of Total Background Noise (1/3 Octave Analysis)

reduces the transmission of noise and vibration to the other parts of the building, especially at low frequencies. The column is separated from the floor slab by boards which extend one ft below the floor slab.

The problem of external mechanical vibrations cannot be completely resolved for two reasons:

a) the wooden construction of the Institute building, and

b) other installations in the building.

The measurements showed that the anechoic chamber cannot be used while the dust chambers and wind tunnel are functioning or while mobile vehicles (trucks and tractors) are passing in front of the Institute.

Total noise in the anechoic chamber was measured several times. It consisted of:

a) background noise,

b) heating system noise,

c) ventilation system noise, and

d) air compressor noise.

The spectrum showed the same values and there were neither practical nor theoretical deviations (Figure 2). The background was measured at intervals for one year between 12:00 and 1:00 pm and during the night. The results were the same in that the heating system noise at the Institute caused an increase in background noise only at frequencies between 10 and 100 Hz, the anechoic chamber ventilation system did not produce an increase in noise, and noise from the air compressor resulted in an increase of one dBA over the whole spectrum. The anechoic chamber had thin outside walls; therefore, measurements could not be made while work was in progress in the dust chamber in a nearby room (mechanical vibrations and noise transmission through the walls).

2.2. Wall Lining

The inside dimensions of the anechoic chamber are governed by the dimensions of the acoustic sources which are being investigated. Usually, in making the acoustic measurements, the microphone is located about one metre from both the noise source and the chamber walls, depending upon the absorption and frequency, see 3. 4. 1. The medium-weight hammer drill was 2 ½ ft long and, with the drill steel attached, it was approximately 3 ft long. In this case, the inside dimensions required would be 16 ½ × 13 ¼ × 10 ft for medium-weight hammer drills. The wedge length depends upon the desired cut-off frequency and, usually, 26 in. is taken to achieve a good measurement at 100-Hz frequency which is accepted as a minimum for industrial noise (2, 4).

By using Danish, Russian, and Belgian experience, the absorbers were constructed in the shape of wedges fabricated from Eccodamp MG (Figure 3) (5, 6, 7, 8, 9, 10, 11). Emerson and Cuming Inc., Canton, Massachusetts, the manufacturer, states that the acoustic absorption properties of this product are equivalent or superior to the AOP-35, usually used in Europe. In addition, AOP-35 is highly flammable, whereas the Eccodamp MG foam is not flammable. The chamber was covered with 584 large wedges (15 × 6 × 6 in.) and 256 small wedges ($5^{3}/_{4}$ × 6 × 6 in.). From the dimensions it is noted that:

a) the dimensions do not correspond to the standard measurements for anechoic rooms; and
b) the cut-off frequency is very high.

For this reason, the measurements have informative values between 400 Hz and absolute values above 400 Hz. In this sense, the measurements were made, and the results have been discussed.

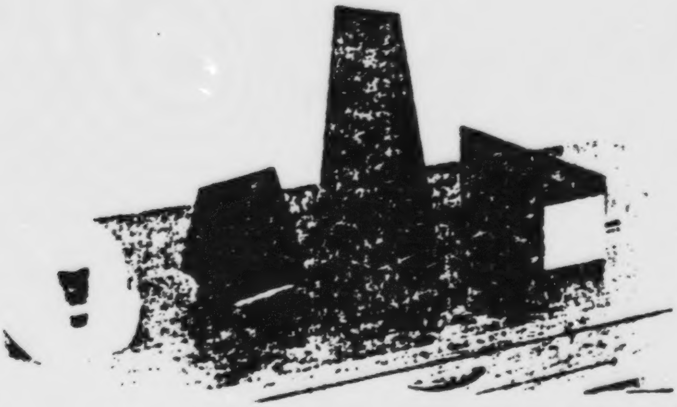

Figure 3: Eccodamp MG Wedges: Large (15 × 6 × 6 in.) and Small (5 3/4 × 6 × 6 in.)

The reflection coefficient of the walls depends upon:

- — the absorbent nature,
- — the absorbent density,
- — the absorbent dimension and form,
- — the manner in which the absorbent is placed, and
- — the eventual position of the resonator.

From a great number of tests with different materials and different forms, Eccodamp MG foam (specific gravity of 35 kg/m^3) was chosen.

2.3. Ventilation System

In practice, most anechoic chambers do not have continual ventilation because of its noise. The required ventilation is usually effected by opening the chamber at regular intervals.

This anechoic chamber was provided with continual ventilation because of the nature of the investigations which had to be made. Air consumption by the medium hammer drill was about 170 cfm, so a fan (Type 12 DLS, cap. 400 cfm) was installed to exhaust this air from the chamber. The details of this ventilation system are shown in Figure 1.

The input silencer was constructed as a labyrinth of small wedges as seen in Figure 1.

The noise reduction due to a quiet-duct silencer is proportional to the length of the duct, the perimeter of the cross section, and the absorbing coefficient of the lining; it is inversely proportional to the cross section.

$$\text{Reduction (dB)} = k\,\frac{RO}{A} \qquad \text{(Eq. 1)}$$

where:

R = length of duct in feet;
O = perimeter of duct in inches;
A = cross section in square inches,

The empirical relationship,

$$k = Qa^{1.4} \qquad \text{(Eq. 2)}$$

has been deduced after Hale J. Sabine,

where:

Q is a constant (12);
a is the absorption coefficient.

From the Equation 1, it may be shown that an increase of the ratio "O/A" indicates that:

i) small ducts are more efficient than large ducts; and
ii) rectangular ducts are more efficient than square ducts.

The noise reduction may be calculated from Eq. 1, except that when this is done, "O" includes both sound-absorbing sides of the splitter.

The relationship between the noise reduction with splitters and without splitters, is given by:

$$R_s = R_d\left(\frac{xN}{x+y}\right) \qquad \text{(Eq. 3)}$$

R_s = reduction with splitters;
R_d = reduction without splitters;
N = number of splitters;
x = length of longest side; and
y = length of shortest side.

The octave band noise reduction characteristics are as follows (13):

	Frequency Bands						
	63	125	250	500	1000	2000	4000
dB	4	5	5	8	16	22	12

2.4. Microphone Orientation System, Electric Installation and the Laboratory for Instrumentation

In order to provide rotational motion of the microphone inside the chamber, a mechanical system was designed. The position of the microphone was controlled through adjustments made outside of the chamber. The measurements in the sphere around the noise source were made using two microphones (Figure 4).

The laboratory in which the instruments were set up is located on the ground floor directly above the anechoic chamber and is connected with it by cables and telephone.

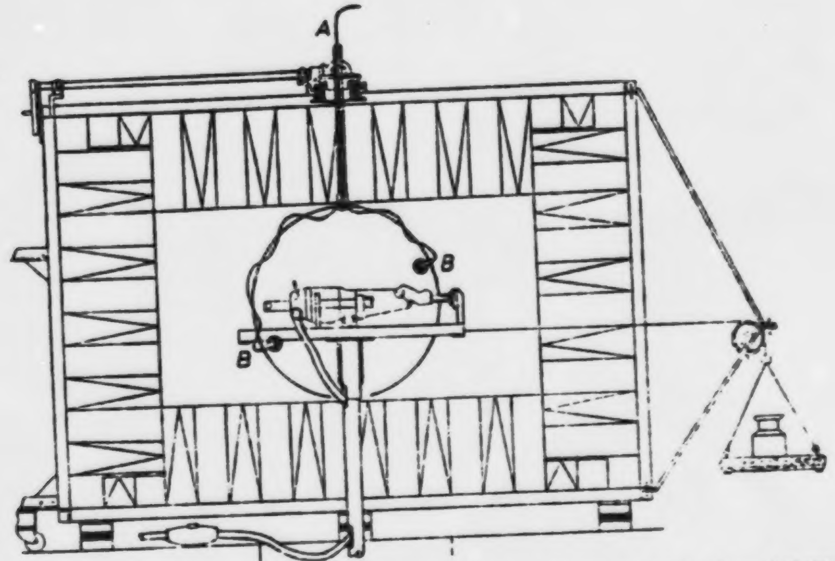

Figure 4: Arrangements for Measuring the Noise from Hammer Drills (A — AO 0023 (10 m)), B — Microphone UA 0052 — 4133)

3. INSTRUMENTATION

The following instruments were used for the testing of the anechoic chamber: Audio Frequency Spectrometer (B and K*, Type 2112, Figure 5), Level Recorder (B and K, Type 2305, Figure 4), and Random Noise Generator (B and K, Type 1402, Figure 11).

Various trade associations and engineering groups have standardized test codes for measuring the noise from certain devices, such as electric motors, transformers, fans, and blowers. These codes are often referenced as part of a specification in order to standardize the measurement procedure to be used in checking for compliance to a maximum noise requirement.

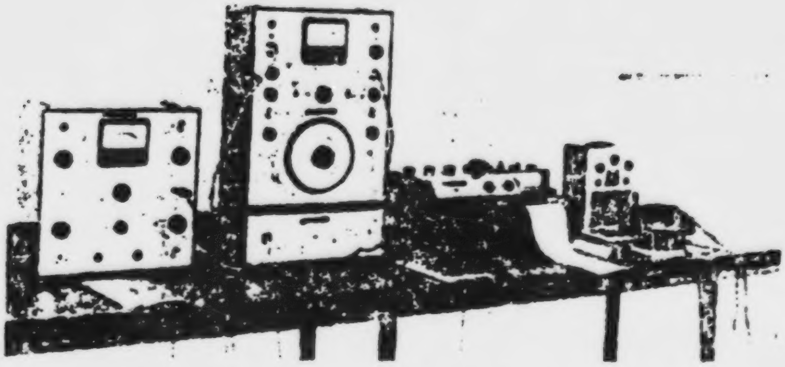

Figure 5: Arrangement for Measuring the Sound Characteristics

3.1. Audio Frequency Spectrometer (B and K, Type 2112)

The audio frequency spectrometer is designed for analyses and linear measurements in acoustics, electro-acoustics, electronics, and vibration in the frequency range 22 to 45,000 Hz. Means for the connection of extension filters are available thereby extending the selective frequency range from 11 to 45,000 Hz. The spectrometer consists of an input circuit, and input amplifier, a filter section, an output amplifier, and a meter circuit.

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* Bruel and Kjaer (Canada) Limited.

3.2. Level Recorder (B and K, Type 2305)

The level recorder is designed for accurate recording of signal levels in the frequency range 2 to 200,000 Hz. Typical applications are recording of spectrograms, frequency response characteristics, reverberation decay curves, and noise and vibration levels. The instrument records either on lined paper or on amplitude/frequency calibrated paper.

3.3. Random Noise Generator (B and K, Type 1402)

The noise generator produces a noise signal with uniform spectrum density in the frequency range 20 to 20,000 Hz having true (normal) Gaussian amplitude distribution.

3.4. Microphones

The B and K condenser microphones are designed for measuring sound. A complete condenser microphone consists of a microphone cartridge and a microphone preamplifier.

It consists essentially of a thin metallic diaphragm mounted close to a rigid back plate. The diaphragm and back plate are electrically insulated from each other and constitute the electrodes of a capacitator.

Two classes of condenser microphones are available, the free field microphone and the pressure microphone. The cartridges available in four different nominal diameters are tabulated below (14, 15).

Microphone Diameters	Free Field	Pressure
1 inch, 23.77 mm	Type 4131	Type 4132
½ inch, 12.70 mm	Type 4133	Type 4134
¼ inch, 6.35 mm	Type 4135	Type 4136
⅛ inch, 3.175 mm		Type 4138

The microphone preamplifier UA 0052 (½ in.) has an extremely high input impedance which presents virtually no load to the microphone cartridge.

The microphone extension cable is available with B and K connectors at both ends. This cable was necessary because of the distance between the instrumentation laboratory and the anechoic chamber (Figures 4 and 11).

3.4.1. Selection of Microphone Orientations

The nature of the sound field, the measurement condition, and the purpose of the measurements determine which class of microphone will give the best data. The five measurement conditions, as shown in Figure 8, will be discussed.

The response of a microphone to a sound field depends upon the location of the microphone with respect to the sound source. The near- and far-field conditions (Figure 6, A and B) relate to the source radiation behaviour as a function of its distance from the sound source and the free-field while the reverberant-field conditions have to do with the external environment. Most sound measurements are made in the far field, because the interest in the total sound radiated from the noise source. The distance between the microphone and the source should be 3 to 4 times the largest dimension of the radiating source. The measured power levels are in best agreement down to values of $r/a = 2$, in which r is the radius of the test hemisphere and a is the maximum motor or machine dimension (1, 16).

No microphone position should be closer to the chamber boundaries than $\lambda/4$ ft, λ being the wavelength of sound at the centre frequency of the lowest frequency band of interest. Both of the above conditions could not be satisfied because the rock drills LION BBC 24 and 25 (Atlas Copco) are about 30 in. long. From these figures the radius (r) can be calculated as:

$$r = 5 \text{ ft.}$$

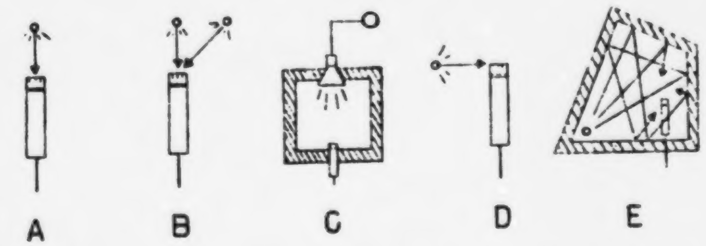

Figure 6: The Five Common Measurement Conditions that May Be Expected when Microphones Are Used (A — Perpendicular incidence — a free field. B — Omnidirectional — a free field. C — Pressure — a small closed cavity. D — Grazing incidence — a diffuse field. E — Random incidence — a diffuse field)

If the lowest frequency band of interest is considered to be 250 Hz, then λ = 4 ft 3 in. The distance (d) from the microphone to the wedges in the chamber is:

$$d = 1 \text{ ft } 3/4 \text{ in.}$$

That is why the measurements in our chamber cannot have absolute values for frequencies above 5 kHz (increase 1 to 1.5 dB). Reflections of sound usually exist (even outdoors), so the field is partly reverberant. The proper microphone must be selected and oriented in the sound field to minimize these effects. The area of the test hemisphere covers the limits of level fluctuations observed with small shifts in microphone position. This apparent variability is caused entirely by reflections. Because of these difficulties, extremely critical measurements are often made in anechoic rooms.

The calibration chart supplied with a condenser microphone cartridge (B and K. Type 4133) shows that the pressure response of the ½-inch microphone

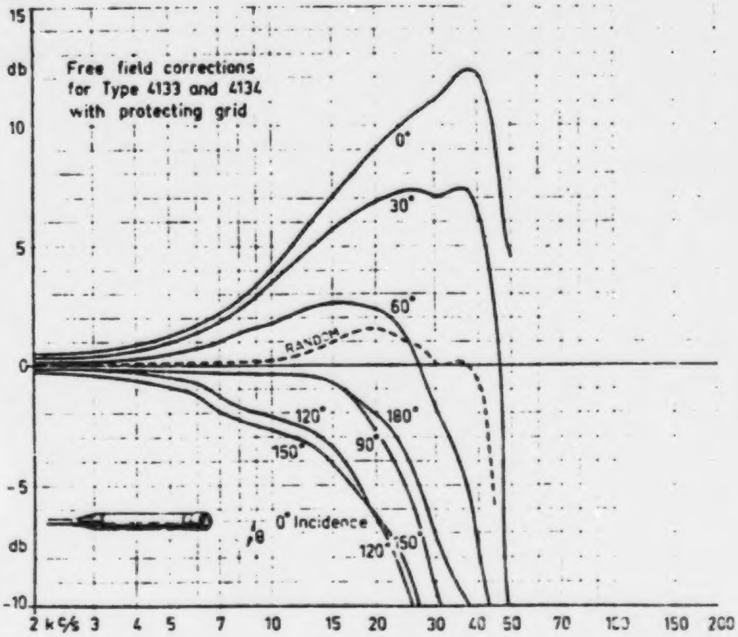

Figure 7: Typical Free-Field Correction Curves to be Added to the Pressure Characteristic of the Half-Inch Microphones, after B and K

flat to 7 kHz. Figure 7 shows that the grazing incidence correction is negligible over that range. The free-field corrections which represent the increase of sound pressure caused by the diffractions of the sound waves around the microphone are important only at high frequencies at which the wavelengths are comparable with the external dimensions of the microphone.

The free-field correction curves for diverse angles of incidence are given in Figure 7. It can be seen that the random incidence (free-field) corrections are very small at audio frequencies. The same microphone will suit for both outdoor and indoor measurements. The grids are individually adjusted during manufacture in order to obtain this characteristic to within 0.2 dB up to 30 kHz and to within 0.5 dB above 30 kHz. This instrumentation, when equipped with the B and K condenser microphone, Type 4133, fulfills the IEC 179 recommendations for precision sound level meters.

Now the microphones can be evaluated for use under the five measurement conditions that were identified earlier herein. The requirements for free-field and pressure microphones and their proper orientation can be given as shown in Table 1.

TABLE 1

Application of Microphones

Measurement Condition	Class of Microphone	Typical Application	Standard
A Perpendicular Incidence	Free-field	Product noise	ISO; ASA
B Omnidirectional Incidence	Pressure (small size) or Corrected free-field	Factory noise	ISO; ASA
C Pressure	Pressure	Calibrate earphones	ISO; ASA
D Grazing	Pressure	Moving sound source	FAA
E Random Incidence	Pressure	Total acoustic power	ASHRAE

A single class of microphone is not adequate for all measurements. Proper application of microphones can provide acoustical data that are of maximum certainty and accuracy.

3.4.2. Windscreen (B and K, UA 0237)

While a microphone is exposed to wind, noise will be generated due to the variation of air pressure on the diaphragm. The three principal reasons for this are:

i) wind velocity variations;
ii) turbulence created around the microphone when it is placed in the wind;
iii) mechanical impacts and uncleanliness (pieces of hard rubber and oil).

In our case, free-field correction curves for windscreen B and K UA 0237 differ in the frequency range 5,000 to 10,000 Hz (Figure 8).

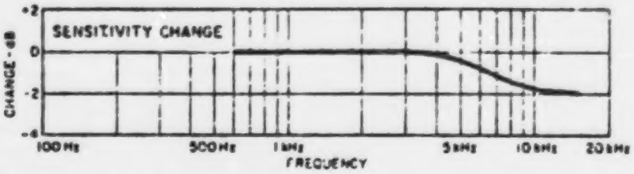

Figure 8: Changes in Sensitivity of a One-Inch Microphone Caused by a Windscreen

4. CALIBRATION

The supplier of the wedge lining for the chamber guaranteed the acoustical absorption qualities of the foam.

In free space, according to the inverse-square law, there will be a decrease of 6 decibels in the sound pressure level for each doubling of the distance. Figures 9 and 10 show the theoretical curve for the inverse-square law, starting with a measurement of half a foot. The acoustic source is located in the centre of the anechoic chamber. In front of the door, the measurement at a distance of 3 feet was not taken because of the door.

Random noise sources are used for tests of the inverse-square law in an anechoic room; therefore, the source size, phasing, and microphone orientation all become critical factors in the accuracy of the calibration (Figure 11).

The sound pressure level in the ⅓ octaves belonging to that octave band are computed. The results (Figures 9 and 10) show that the cut-off frequency occurs between 250 and 500 Hz, just as it was foreseen prior to the construction. In a free field, a tolerance of one dB in measurements technique is acceptable.

The two sides of the anechoic chamber show an approximately symmetrical picture. The measurements taken in front of the door (Figure 9) show greater deviations for the frequencies of 2000 Hz and 4000 Hz at a distance of 1 ½ to 2 ½ feet from the noise source. This indicates that the acoustic seal between the door and the chamber is not sufficient to provide good attenuation. At a distance of 1 ½ ft in the zone of our measurements, the deviation is 1.3 dB which is acceptable because, for the frequencies 2000 and 8000 Hz, the results were good. The measurements taken opposite the door at the frequency of 500 Hz show a deviation at the distance of 2 to 3 ft which is out of the radius of the measurement sphere. The deviation occurs also at 2000 Hz at the distance of 3 ft (÷ 1.6 dB). This result is accidental because, at the frequencies of 1000 Hz and 4000 Hz, the results are good. The measuring direction opposite the door in the anechoic chamber is the most favourable.

By measurements (⅓ octave band) it is confirmed that the limit of the cut-off frequency is between 350 and 400 Hz. As a general rule, the greater the attenuation desired at low frequency, the heavier and more expensive the room will be.

The maximum values of the deviation of sound pressure from the inverse-square law as a function of the distance from a point source are acceptable between 400 Hz and 3 kHz.

5. CONCLUSIONS

The anechoic chamber can be used for good measurements of noise from light and medium hammer drills.

The noise from the ventilation system can be attenuated to such a degree that the ventilator can be used during testing of the hammer drill.

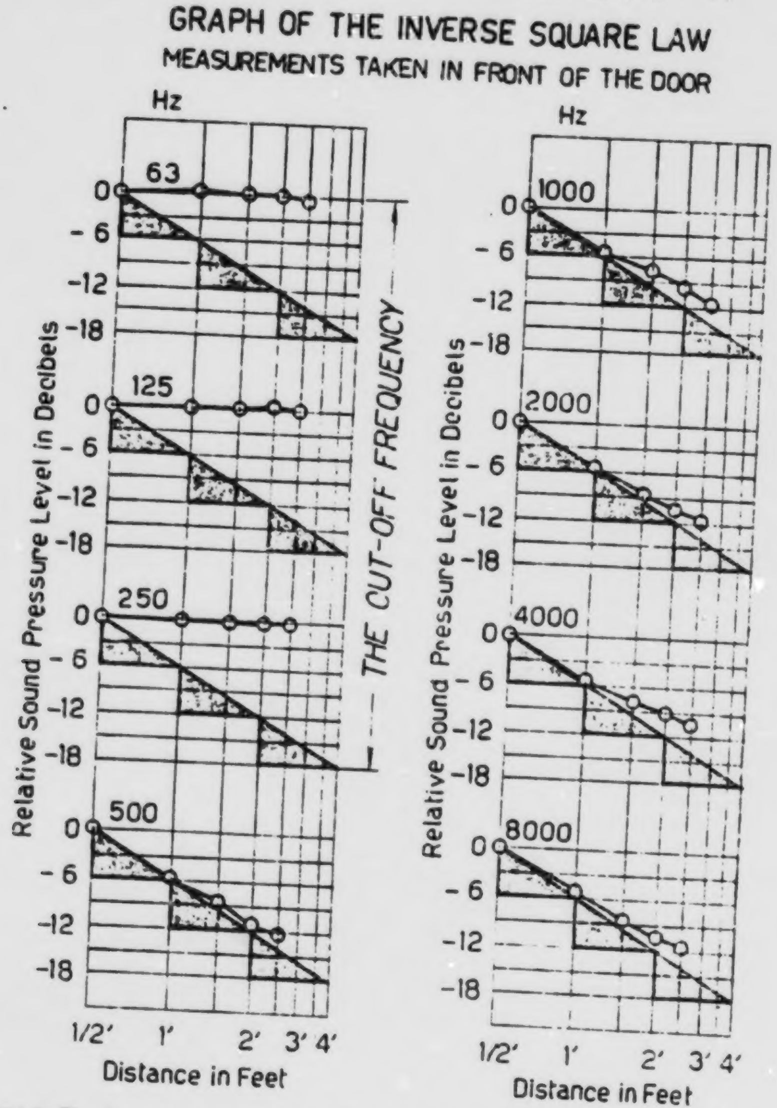

Figure 9: The Inverse-Square Law of the Anechoic Chamber (Front of the Door)

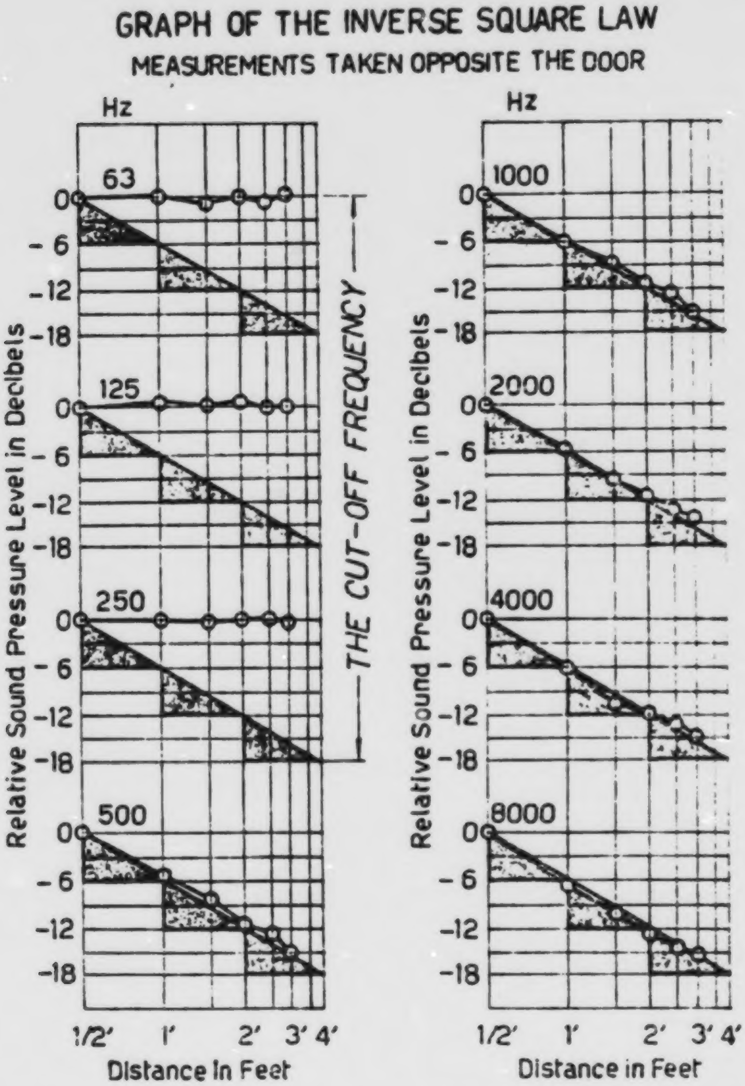

Figure 10: The Inverse-Square Law of the Anechoic Chamber (Opposite the Door)

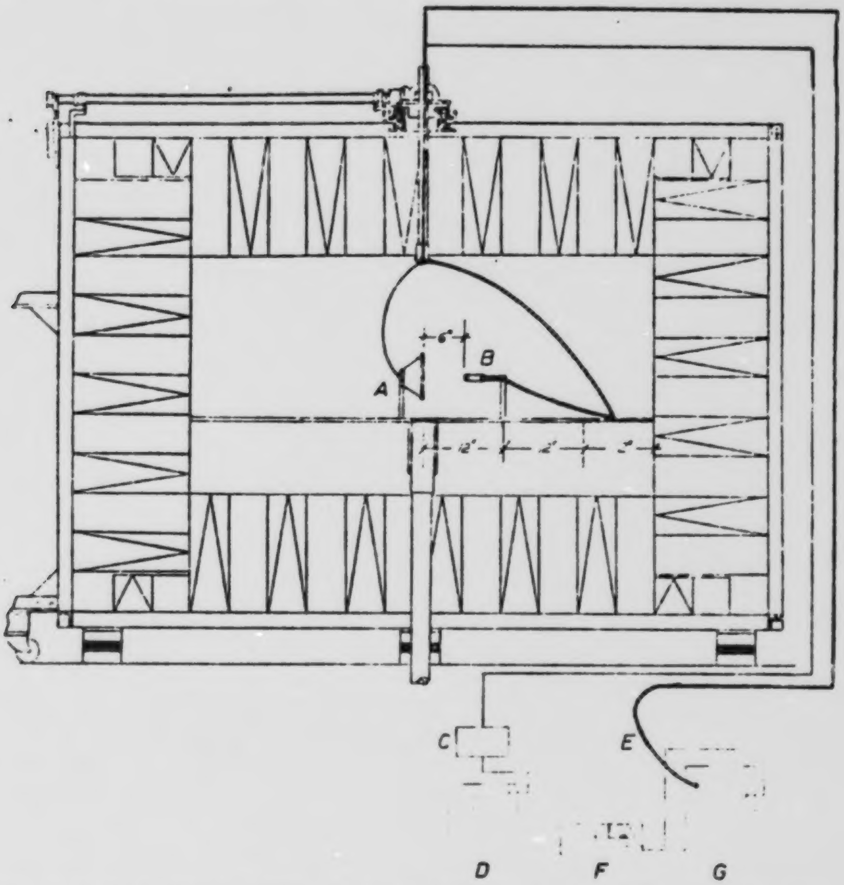

Figure 11: Measuring Arrangements for the Testing of the Anechoic Chamber (A — Loudspeaker, B — Microphone UA 6052 — 4133, C — Power Amplifier, D — Random Noise, Generator 1042, E — AO 0028 (10 m), F — Level Recorder 2305, G — Audio Frequency Spectrometer 2112)

The insulation against noise in the vicinity of the building is good above 95 dB at frequencies between 500 and 8000 Hz.

The system for the abatement of hammer drill noise can be further improved.

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RAZVOJ KOMORE BEZ ODJEKA

U Institutu za istraživanje mineralnih sirovina u St. Hilaire (ogranak McGill Univerziteta u Montrealu), konstruisana je gluha komora (komora bez odjeka, bez refleksije zvuka) za merenje buke kod lakih i srednje teških bušaćih čekića. Glavne osobine komore su jednostavnost i jeftinoća.

Osnovne vanjske dimenzije komore su 9 × 6 × 6 ft, i unutrašnje 6 × 3 × 3 ft. Obložena je diedarskim rogljevima iz plastične pene Eccodamp MG (specifične težine 35 kg/m^3). Komora ima kontinualnu ventilaciju i poduprta je gumenim podlogama. To omogućava da prirodna frekvenca pod teretom bude manja od 7 Hz. Izolacija protiv buke u okolini u zgradi je dobra u odnosu na naša merenja. Oprema Brüel i Kjaer (B & K) upotrebljena je kod svih merenja. Za merenje je izrađen orijentacioni sistem za mikrofone, zatim za kablovske i električne instalacije.

Na kraju, izvršena su merenja i komora je kalibrirana u pogledu slobodnog rasprostiranja zvuka. Kalibracija predviđa »cut-off-frequency« na 400 Hz. Ova merenja pokazuju da komora može biti upotrebljena za dobra merenja iznad 400 Hz i pod krajnje neugodnim vanjskim okolnostima.

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Mise au point d'une méthode normalisée de mesure de l'exposition au bruit

par

M. Savich* et W. Stefanich**

RÉSUMÉ

Pour évaluer l'exposition aux bruits environnementaux, il convient d'examiner deux variables : le niveau de pression acoustique et le temps d'exposition.

À cette fin, on a construit un pied de microphone universel utilisable dans les mines. Le pied universel est fixé sur l'articulation du trépied et il comporte les éléments suivants : bride de serrage de la tige d'extension du microphone, tige support, tige d'extension, support du microphone et contre-poids. Afin de réduire l'effet de vibration sur le microphone, des extensions en caoutchouc ont été installées sur les pieds du trépied. Un prototype a été essayé et a fourni des résultats entièrement satisfaisants.

Toutes les difficultés que le Bureau des mines avait éprouvées dans les mesures ont été éliminées par notre méthode.

Sont incluses des formules expliquant comment analyser les résultats en respectant la loi de Walsh-Healy dans laquelle la somme de deux ou plusieurs périodes d'exposition au bruit est supérieure à l'unité.

Bruit : Exposition : Mesure : Pied universel : Formules

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Un exemple de mesure pratique est aussi inclus et l'on montre comment ces mesures peuvent être appliquées simplement pour le contrôle administratif et technique dans les mines canadiennes.

Development of a Standard Method for Testing Noise Exposure

by

M. Savich* and W. Stefanich**

- - - - - - - - - - - - - - - -

ABSTRACT

In order to assess environmental noise exposure, two variables must be observed: sound pressure level and exposure time.

For these reasons, a microphone stand for universal use in mines was constructed. The universal attachment is attached to the tripod joint and consists of the following pieces: microphone extension rod clamp, holding rod, extension rod, microphone holder and counterweight. To reduce the effect of vibration on the microphone, rubber tubing extensions for the tripod legs were provided. A prototype was tested and showed totally satisfactory results.

All difficulties which the Bureau of Mines had encountered in measuring were eliminated by our method.

Forms are included which show how to perform the analysis of results in keeping with the Walsh-Healey Act in which the sum of two or more periods of noise exposure exceeds unity.

Noise: Exposure: Measurement: Universal Attachment: Forms

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An example of a practical measurement is also included, showing how it can be simply applied for administrative and engineering control in Canadian mines.

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1. INTRODUCTION

Noise exposure data should be used as a guide but not as a fine line between safe and unsafe levels. To assess environmental noise exposure in keeping with the Walsh Healey Public Contracts Act in effect October 1, 1969, two variables must be observed: sound level and exposure time per shift. For these reasons, a microphone stand for universal use in mines was constructed (Figure 1).

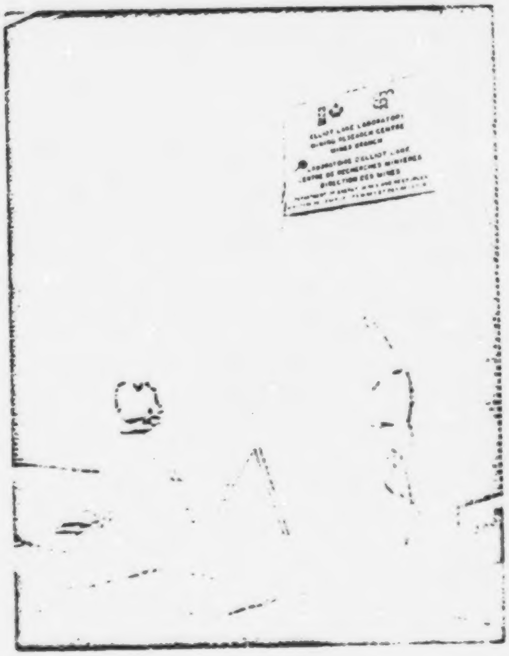
ELLIOT LAKE LABORATORY
MINING RESEARCH CENTRE
MINES BRANCH
LABORATOIRE D'ELLIOT LAKE
CENTRE DE RECHERCHES MINIERES
DIRECTION DES MINES

Figure 1: Universal Attachment, a Microphone Stand for Use in Mines.

For our equipment (sound level meter and attachment), tables were drawn up, applied in practice and corrected several times in order to obtain clear and easily surveyed results. The total noise exposure per shift is also described.

2. PRINCIPLE OF SURVEY PROCEDURE

The sound level meter (B and K*, Type 2205) was used to observe the sound levels. The sound level meter was operated on the A-weighted slow response and calibrated with the calibrator (B and K, Type 4230) according to the manufacturer's instruction. Sound level measurements were taken usually within 1 metre of the miner's ear; however, they should not be taken at his head.

2.1 U.S. Bureau of Mines Measurements

"The observer should make note of all such possible reflective surfaces and position himself to minimize obstructing wave energy. The meter should be held away from the surveyor at or nearly at arm's length." (1). The intermittency and short duration of sound levels inherent in United States mines created several problems with the use of standard sound level meters (2) (Figure 2):

1. The short duration at each level does not allow sufficient time to make the prescribed number of readings. Minimum five seconds are required for each observation.
2. It is impossible for one man to time the various operations, take sound level readings, time readings, take notes, and hold instruments which depend upon the angle of incidence of the sound

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* Bruel and Kjaer

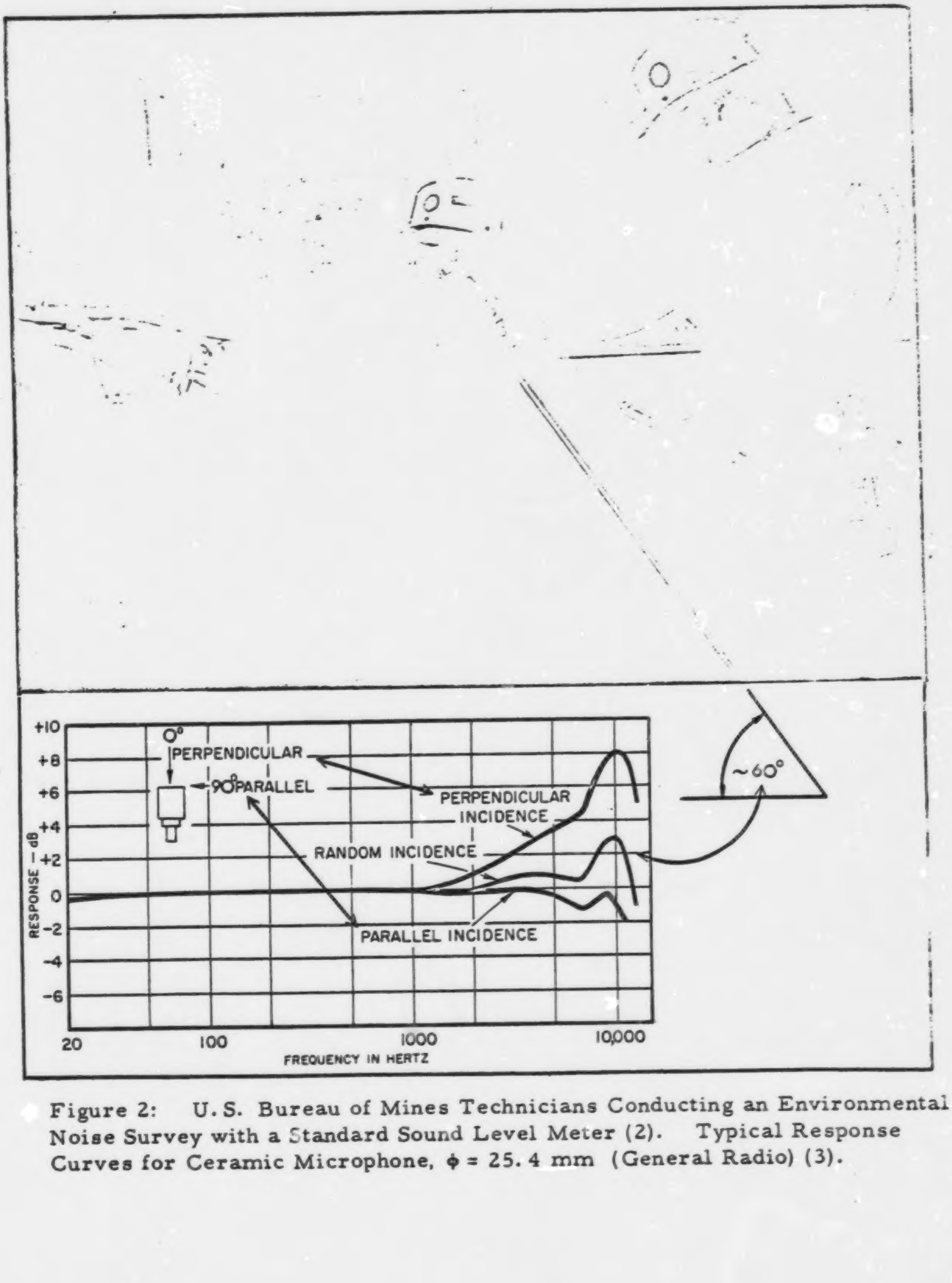

Figure 2: U.S. Bureau of Mines Technicians Conducting an Environmental Noise Survey with a Standard Sound Level Meter (2). Typical Response Curves for Ceramic Microphone, $\phi = 25.4$ mm (General Radio) (3).

on the microphone.

3. The surveyor cannot stand next to the operator because of safety precautions.

The total duration of exposure time in hours was determined by full-shift time studies and partial-shift time studies. The standards on noise exposures prescribed under the Walsh Healey Public Contracts Act in effect October 1, 1969 will be applied in the analysis of results obtained in this study.

2.2 Measurements with the Universal Attachment

The universal attachment consists of the following:

Tripod (B and K)(Appendix A-1),
Microphone extension rod clamp (Appendix A-2),
Holding rod (Appendix A-2 and A-3),
Extension rod (Appendix A-3),
Microphone holder (Appendix A-3), and
Counterweight (Appendix A-4).

The microphone extension rod clamp is attached to the tripod joint. An aluminum tube holding rod, 1500 mm long and 19.1 mm diameter, is put into the clamp. Another tube extension rod, 1500 mm long and 15.9 mm diameter, is put into the first tube. On one end of the extension rod is an off-center cam lock which holds the tube firmly, and on the other end is the elbow to which the microphone receiving slot is attached. The elbow serves to adjust the angle of incidence (Figure 3). Different types of microphones have different response curves; therefore the sound waves have different angles of incidence. The holding rod counterbalance acts as a stabilizer for the whole

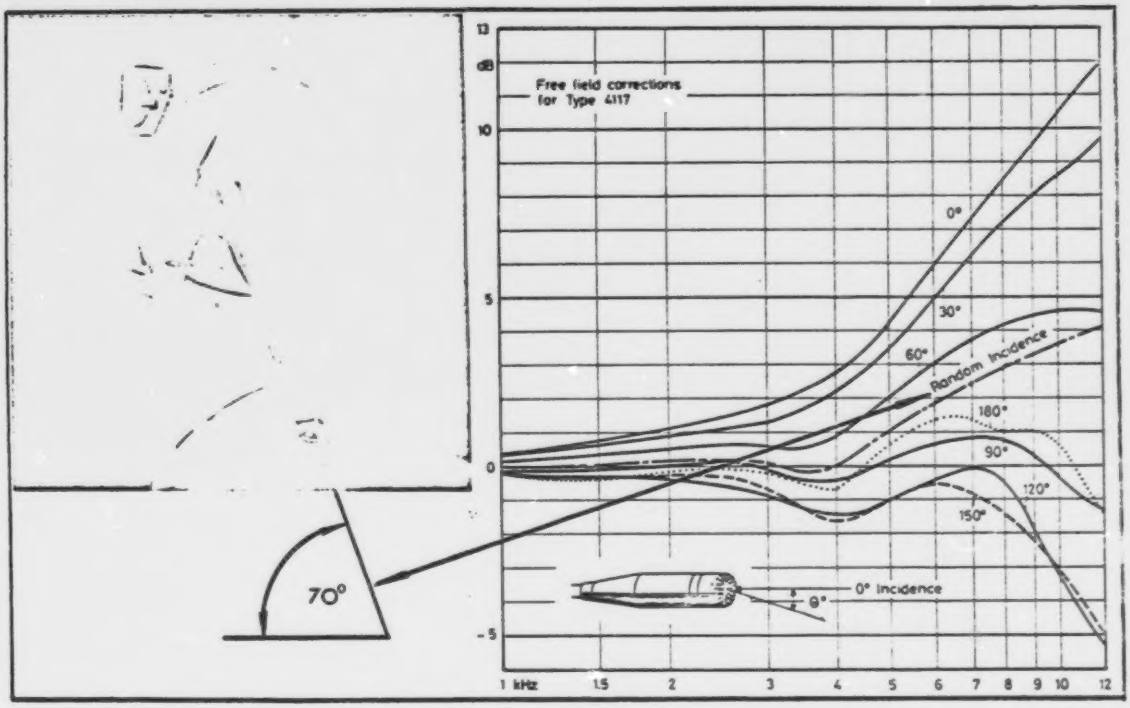

Figure 3: Measuring Noise Levels at Operator's Ear by Technician, Elliot Lake Laboratory. Free-field correction curves for the microphone, $\phi = 25.4$ mm (B and K, Type 4117) (4).

system. The counterbalance weights are determined by spring balance for extreme cases of overloading. The technical description with the design is given in detail in Appendix A. At the locations where noise measurements have to be made (5), interference from vibrations is likely and the tripod legs are mounted on antivibration pads consisting of rubber tubing, with the following results:

1. there was no increase in noise because of vibration, and
2. the tripod was stable because it would not slip.

Figure 4: Rubber Tubing Extensions for Tripod Legs which Provide Isolation for Microphone.

3. TECHNIQUE FOR ANALYSIS OF RESULTS

The sound level meter (B and K, Type 2205) was used to determine the permissible noise levels whether they are concerned with unsatisfactory mining conditions, according to the Walsh-Healey Act, or health hazards, etc. According to the formula in which the sum of two or more periods of noise exposure exceeds unity, in Appendix B forms are included showing how it is possible to perform the analysis of results. The tables are set up in such a way that the data can be used directly for graphic statistics or the computer program (Appendix B). The Converting Tables are set up for the intermittency and short duration of sound levels up to 7 minutes (Appendix C).

The following forms used in metal mines have been composed:

1. Plant-Noise Survey Form, according to the Walsh-Healey Act;
2. Noise Survey Form (Converting Form), according to the Walsh-Healey Act;
3. Noise Survey Form, according to sound level meter and the Walsh-Healey Act;
4. Converting Tables, according to our experience of measurements:
    - from 0 to 1 minute, by seconds, expressed in hours;
    - from 1 to 2 minutes, by seconds, expressed in hours;
    - from 2 to 3 minutes, by seconds, expressed in hours;
    - from 3 to 4 minutes, by seconds, expressed in hours;
    - from 4 to 5 minutes, by seconds, expressed in hours;
    - from 5 to 6 minutes, by seconds, expressed in hours;
    - from 6 to 7 minutes, by seconds, expressed in hours;
    - from 1 to 60 minutes, by minutes, expressed in hours.

An example of a practical measurement in mines, "Crusher", is included in Appendix D. If the data are carefully analyzed, full data of total noise exposure can be obtained which could be simply applied for administrative and engineering control in Canadian mines. The graphic diagram was made and the computer program was used to study elementary statistics (Appendix D).

4. CONCLUSIONS

Construction of the universal attachment made the technical development possible for measuring noise level criteria (Table 1). The short duration at each level is sufficient time to make the prescribed number of readings. Because the surveyor only measures, two seconds are required for each observation (Figure 1 and Appendix A-1). The most accurate

Table 1
COMPARISON OF RESULTS

	U.S. Bureau of Mines Pittsburgh, Pa.	Elliot Lake Laboratory Mines Branch, E.M.R.
Minimum time to prescribed number of readings	5 sec.	2 sec.
Sound Level Meter	To hold in hand, First Surveyor	Operation with Sound Level Meter and microphone on tripods
Stopwatch	Second surveyor	First surveyor
Take notes	Second surveyor	First surveyor
Angle of incidence of the sound	Variable	Constant
Vibration isolation	Body of surveyor	Rubber tubing extensions on tripod legs
Own safety	None	Yes
Number of surveyors	Two	One

measurements would be obtained by using a constant intermediate angle of incidence to approximate the response for random incidence. The surveyor is always in a safe place and only one man is required. The function of environment in mining should be very simple and useful in concept.

5. ACKNOWLEDGEMENTS

The authors wish to acknowledge the contribution of G. Zahary, G. Knight and R. Tervo, and wish to thank J. Smith for his assistance in the design and construction of the microphone extension rod and other necessary components.

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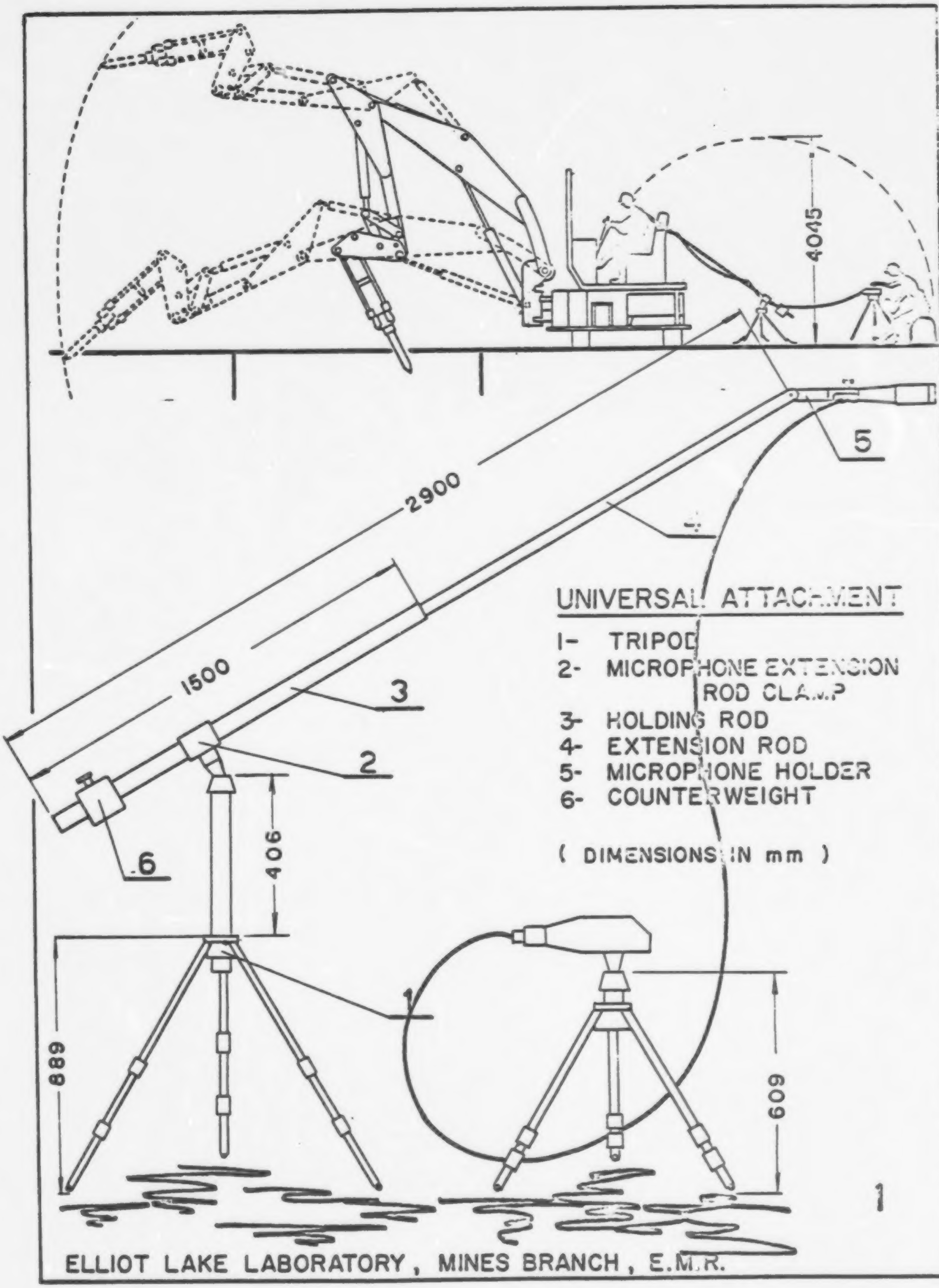
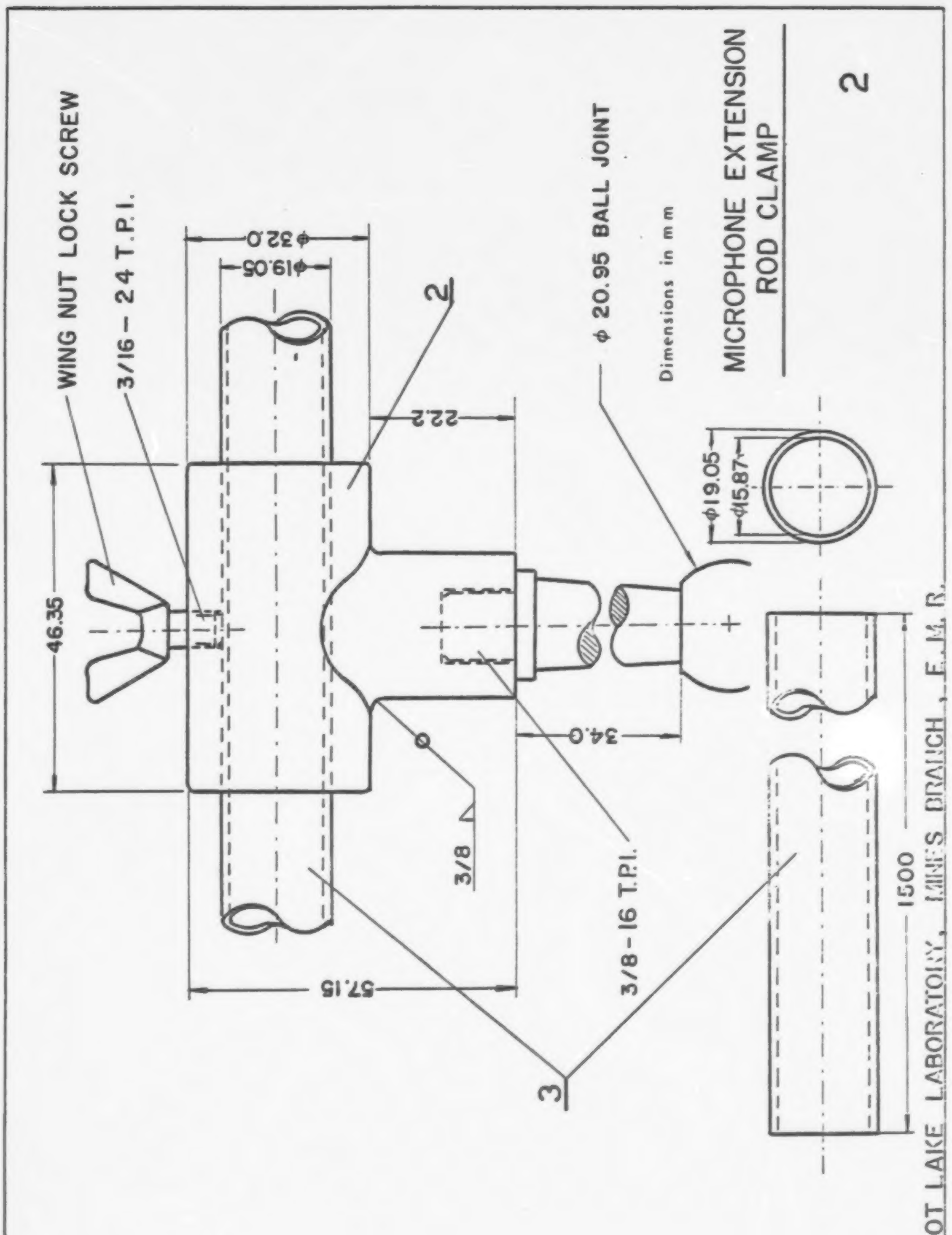
3. Peterson, A.P.G. and Gross, E.E. Jr., "Handbook of Noise Measurement", General Radio Co., 6th Ed., West Concord, Mass., 1967.
4. Bruel and Kjaer, Data from sales literature: Piezoelectric Microphone Type 4117, July 1971.
5. American Industrial Hygiene Association, "Industrial Noise Manual", Detroit, Mich., 2nd Ed., 1966.

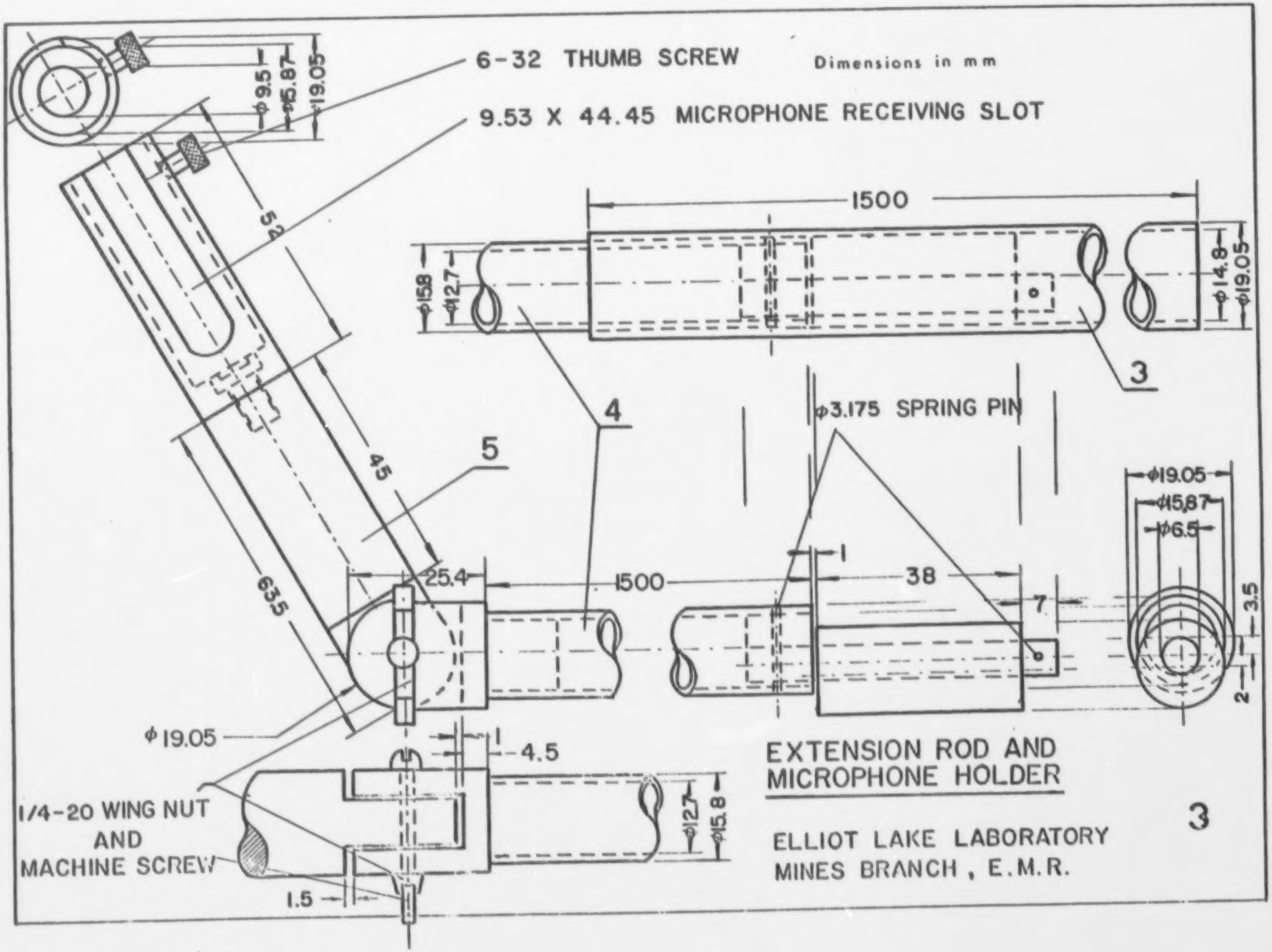
APPENDIX A

UNIVERSAL ATTACHMENT DESIGN


4045
5
2900
4
UNIVERSAL ATTACHMENT
1- TRIPOD
2- MICROPHONE EXTENSION ROD CLAMP
3- HOLDING ROD
4- EXTENSION ROD
5- MICROPHONE HOLDER
6- COUNTERWEIGHT
(DIMENSIONS IN mm)
1500
3
2
6
406
1
889
609
ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

1

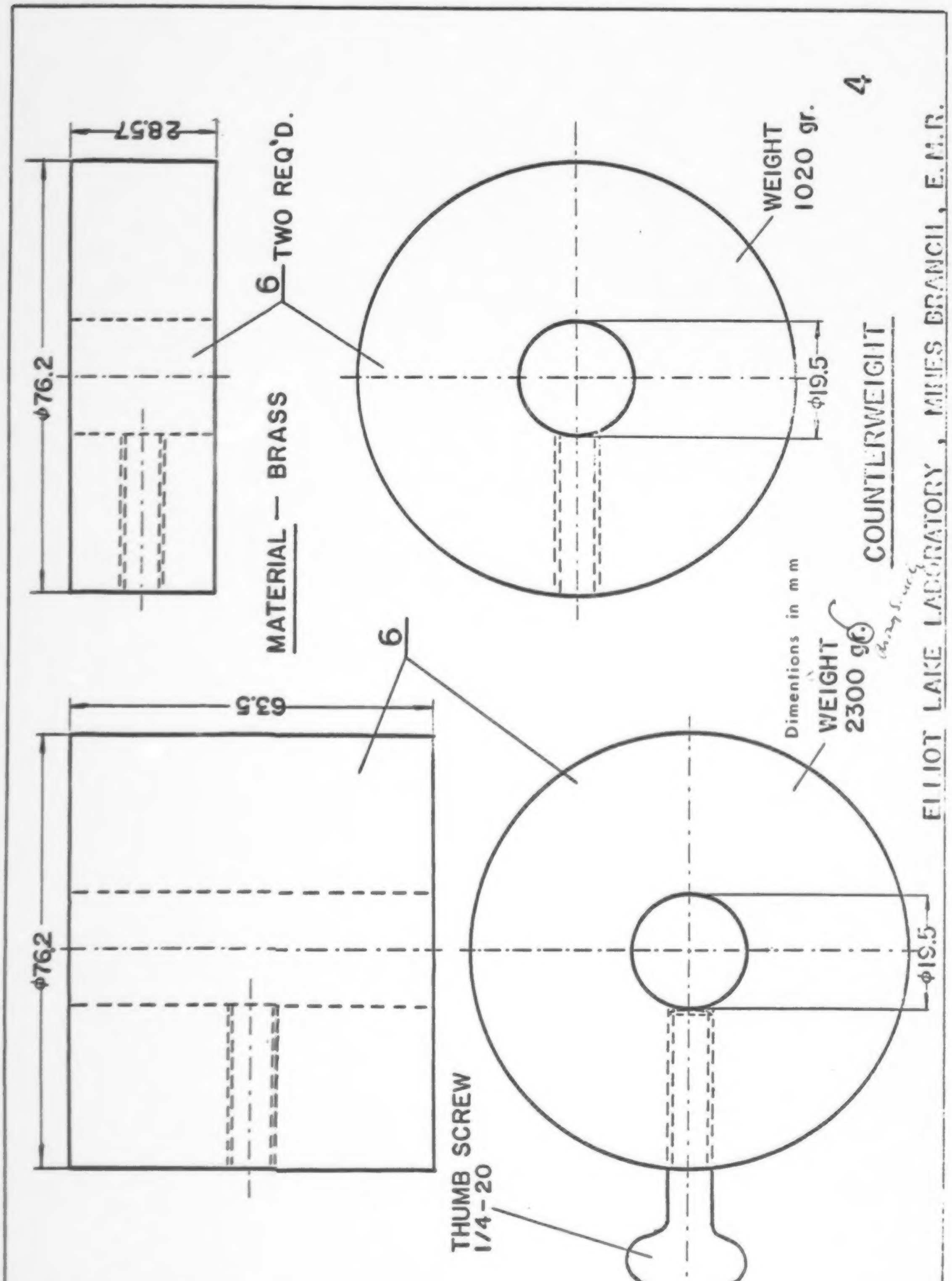

WING NUT LOCK SCREW
3/16 – 24 T.P.I.
46.35
φ32.0
φ19.05
2
22.2
φ 20.95 BALL JOINT
Dimensions in mm
MICROPHONE EXTENSION ROD CLAMP
2
φ19.05
φ15.87
34.0
3/8
3/8 – 16 T.P.I.
57.15
3
1500
ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.


6-32 THUMB SCREW
Dimensions in mm
9.53 X 44.45 MICROPHONE RECEIVING SLOT
φ9.5
φ15.87
19.05
52
45
63.5
25.4
5
4
1500
φ15.8
φ12.7
1500
φ14.8
φ19.05
3
φ3.175 SPRING PIN
1
38
7
φ19.05
φ15.87
φ6.5
3.5
2
φ19.05
4.5
1/4-20 WING NUT
AND
MACHINE SCREW
1.5
φ12.7
φ15.8

EXTENSION ROD AND
MICROPHONE HOLDER

3

ELLIOT LAKE LABORATORY
MINES BRANCH, E.M.R.


φ76.2
28.57
6
TWO REQ'D.
MATERIAL — BRASS
φ19.5
WEIGHT
1020 gr.
4
φ76.2
63.5
6
Dimentions in mm
WEIGHT
2300 gr.
φ19.5
THUMB SCREW
1/4-20
COUNTERWEIGHT
ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

APPENDIX B

NOISE SURVEY FORMS

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Plant-Noise Survey Form

DATE:
METER #:

LOCATION: ....
....
NUMBER OF PERSONNEL EXPOSED: ....
WEARING EAR PROTECTION? ☐ yes ☐ no

OPERATOR: ....

Equipment ....
Manufacture ....
Steel type ....
Length (m.) ....
Bit type ....
Muffler type ....
Air kPa ....
Water kPa ....
Airflow m³./min. ....
Blow rate (blow/min.) ....
Penetration m./min. ....
Rock type ....

DIAGRAM:
(Show measuring location with an X.)

NOTES: ....
....

	dBA MAX LEVEL	EXPOSURE TIME If necessary, note time of day	C TOTAL DURATION IN HOURS PER DAY	T PERMISSIBLE HOURS PER DAY	C/T
MAXIMUM LEVELS AS MEASURED ON THE "As" SCALE OF THE SOUND-LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.	OVER 115			NONE	
	115			¼	
	110			½	
	105			1	
	102			1½	
	100			2	
	97			3	
	95			4	
	92			6	
	90			8	
	UNDER 90			ANY	0
IMPACT CHECK MUST BE UNDER 140 dB PEAK SOUND PRESSURE LEVEL AS MEASURED WITH AN IMPACT NOISE ANALYZER, OR BE UNDER 120 dB AS MEASURED WITH A SOUND LEVEL METER ON C WEIGHTING, FAST RESPONSE, 140 dB FULL SCALE RANGE.		MAX - dB(C)		TOTAL To comply with regulations, total cannot be more than 1.	

RECOMMENDATIONS: ....
.... SIGNED: ....

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Noise Survey Form (CONVERTING FORM)

DATE :
METER #:
SHEET :

No.	dBA		No.	dBA		No.	dBA		No.	dBA		No.	dBA		No.	dBA	
	secs	hours		secs	hours		secs	hours		secs	hours		secs	hours		secs	hours

LOCATION: ....

OPERATOR: ....

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Noise Survey Form

MAXIMUM LEVELS AS MEASURED ON THE "A_S" SCALE OF THE SOUND LEVEL METER IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.

DATE:
METER #:
SHEET:

No.	EXPOSURE		NOTES	No.	EXPOSURE		NOTES	No.	EXPOSURE		NOTES
	TIME	dBA			TIME	dBA			TIME	dBA	

OPERATOR:.......................

APPENDIX C

CONVERTING TABLES

CONVERTING TABLE From 0 to 1 minute

Exposure Time		Exposure Time		Exposure Time	
in seconds	in hours	in seconds	in hours	in seconds	in hours
1	0.0003	21	0.0058	41	0.0113
2	0.0005	22	0.0061	42	0.0116
3	0.0008	23	0.0063	43	0.0119
4	0.0011	24	0.0066	44	0.0122
5	0.0013	25	0.0069	45	0.0125
6	0.0016	26	0.0072	46	0.0127
7	0.0019	27	0.0075	47	0.0130
8	0.0022	28	0.0077	48	0.0133
9	0.0025	29	0.0080	49	0.0136
10	0.0027	30	0.0083	50	0.0138
11	0.0030	31	0.0086	51	0.0141
12	0.0033	32	0.0088	52	0.0144
13	0.0036	33	0.0091	53	0.0147
14	0.0038	34	0.0094	54	0.0150
15	0.0041	35	0.0097	55	0.0152
16	0.0044	36	0.0100	56	0.0155
17	0.0047	37	0.0102	57	0.0158
18	0.0050	38	0.0105	58	0.0161
19	0.0052	39	0.0108	59	0.0163
20	0.0055	40	0.0111	60	0.0166

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0-1

CONVERTING TABLE

From 1 to 2 minutes

Exposure Time			Exposure Time			Exposure Time		
in		converting	in		converting	in		converting
min	sec	in hours	min	sec	in hours	min	sec	in hours
1	0	0. 0166	1	20	0. 0221	1	40	0. 0277
1	1	0. 0168	1	21	0. 0224	1	41	0. 0279
1	2	0. 0171	1	22	0. 0227	1	42	0. 0282
1	3	0. 0174	1	23	0. 0229	1	43	0. 0285
1	4	0. 0177	1	24	0. 0232	1	44	0. 0288
1	5	0. 0179	1	25	0. 0235	1	45	0. 0291
1	6	0. 0182	1	26	0. 0238	1	46	0. 0293
1	7	0. 0185	1	27	0. 0241	1	47	0. 0296
1	8	0. 0188	1	28	0. 0243	1	48	0. 0299
1	9	0. 0191	1	29	0. 0246	1	49	0. 0302
1	10	0. 0193	1	30	0. 0249	1	50	0. 0304
1	11	0. 0196	1	31	0. 0252	1	51	0. 0307
1	12	0. 0199	1	32	0. 0254	1	52	0. 0310
1	13	0. 0202	1	33	0. 0257	1	53	0. 0313
1	14	0. 0204	1	34	0. 0260	1	54	0. 0316
1	15	0. 0207	1	35	0. 0263	1	55	0. 0318
1	16	0. 0210	1	36	0. 0266	1	56	0. 0321
1	17	0. 0213	1	37	0. 0268	1	57	0. 0324
1	18	0. 0216	1	38	0. 0271	1	58	0. 0327
1	19	0. 0218	1	39	0. 0274	1	59	0. 0329

Elliot Lake Laboratory, Mines Branch, E. M. R.

CONVERTING TABLE

From 2 to 3 minutes

Exposure Time			Exposure Time			Exposure Time		
in		converting in hours	in		converting in hours	in		converting in hours
min	sec		min	sec		min	sec	
2	0	0.0333	2	20	0.0388	2	40	0.0444
2	1	0.0335	2	21	0.0391	2	41	0.0446
2	2	0.0338	2	22	0.0394	2	42	0.0449
2	3	0.0341	2	23	0.0397	2	43	0.0452
2	4	0.0344	2	24	0.0399	2	44	0.0455
2	5	0.0346	2	25	0.0402	2	45	0.0458
2	6	0.0349	2	26	0.0405	2	46	0.0460
2	7	0.0352	2	27	0.0408	2	47	0.0463
2	8	0.0355	2	28	0.0410	2	48	0.0466
2	9	0.0358	2	29	0.0413	2	49	0.0469
2	10	0.0360	2	30	0.0416	2	50	0.0471
2	11	0.0363	2	31	0.0419	2	51	0.0474
2	12	0.0366	2	32	0.0421	2	52	0.0477
2	13	0.0369	2	33	0.0424	2	53	0.0480
2	14	0.0371	2	34	0.0427	2	54	0.0483
2	15	0.0374	2	35	0.0430	2	55	0.0485
2	16	0.0377	2	36	0.0433	2	56	0.0488
2	17	0.0380	2	37	0.0435	2	57	0.0491
2	18	0.0383	2	38	0.0438	2	58	0.0494
2	19	0.0385	2	39	0.0441	2	59	0.0496

Elliot Lake Laboratory, Mines Branch, E. M. R.

2-3

CONVERTING TABLE

From 3 to 4 minutes

Exposure Time			Exposure Time			Exposure Time		
in		converting	in		converting	in		converting
min	sec	in hours	min	sec	in hours	min	sec	in hours
3	0	0.0500	3	20	0.0558	3	40	0.0611
3	1	0.0502	3	21	0.0561	3	41	0.0613
3	2	0.0505	3	22	0.0563	3	42	0.0616
3	3	0.0508	3	23	0.0566	3	43	0.0619
3	4	0.0511	3	24	0.0569	3	44	0.0622
3	5	0.0513	3	25	0.0572	3	45	0.0625
3	6	0.0516	3	26	0.0575	3	46	0.0627
3	7	0.0519	3	27	0.0577	3	47	0.0630
3	8	0.0522	3	28	0.0580	3	48	0.0633
3	9	0.0525	3	29	0.0583	3	49	0.0636
3	10	0.0527	3	30	0.0586	3	50	0.0638
3	11	0.0530	3	31	0.0588	3	51	0.0641
3	12	0.0533	3	32	0.0591	3	52	0.0644
3	13	0.0536	3	33	0.0594	3	53	0.0647
3	14	0.0538	3	34	0.0597	3	54	0.0650
3	15	0.0541	3	35	0.0597	3	55	0.0652
3	16	0.0544	3	36	0.0600	3	56	0.0655
3	17	0.0547	3	37	0.0602	3	57	0.0658
3	18	0.0550	3	38	0.0605	3	58	0.0661
3	19	0.0552	3	39	0.0608	3	59	0.0663

Elliot Lake Laboratory, Mines Branch, E. M. R.

CONVERTING TABLE From 4 to 5 minutes

Exposure Time			Exposure Time			Exposure Time		
in		converting	in		converting	in		converting
min	sec	in hours	min	sec	in hours	min	sec	in hours
4	0	0.0666	4	20	0.0721	4	40	0.0777
4	1	0.0668	4	21	0.0724	4	41	0.0779
4	2	0.0671	4	22	0.0727	4	42	0.0782
4	3	0.0674	4	23	0.0729	4	43	0.0785
4	4	0.0677	4	24	0.0732	4	44	0.0788
4	5	0.0680	4	25	0.0735	4	45	0.0791
4	6	0.0683	4	26	0.0738	4	46	0.0793
4	7	0.0686	4	27	0.0741	4	47	0.0796
4	8	0.0689	4	28	0.0743	4	48	0.0799
4	9	0.0691	4	29	0.0746	4	49	0.0802
4	10	0.0693	4	30	0.0749	4	50	0.0804
4	11	0.0696	4	31	0.0752	4	51	0.0807
4	12	0.0699	4	32	0.0754	4	52	0.0810
4	13	0.0702	4	33	0.0757	4	53	0.0813
4	14	0.0704	4	34	0.0760	4	54	0.0816
4	15	0.0707	4	35	0.0763	4	55	0.0818
4	16	0.0710	4	36	0.0766	4	56	0.0821
4	17	0.0713	4	37	0.0768	4	57	0.0824
4	18	0.0716	4	38	0.0771	4	58	0.0827
4	19	0.0718	4	39	0.0774	4	59	0.0829

Elliot Lake Laboratory, Mines Branch, E. M. R.

4-5

CONVERTING TABLE From 5 to 6 minutes

Exposure Time			Exposure Time			Exposure Time		
in		converting	in		converting	in		converting
min	sec	in hours	min	sec	in hours	min	sec	in hours
5	0	0. 0833	5	20	0. 0888	5	40	0. 0944
5	1	0. 0835	5	21	0. 0891	5	41	0. 0946
5	2	0. 0838	5	22	0. 0894	5	42	0. 0949
5	3	0. 0841	5	23	0. 0896	5	43	0. 0952
5	4	0. 0844	5	24	0. 0899	5	44	0. 0955
5	5	0. 0846	5	25	0. 0902	5	45	0. 0958
5	6	0. 0849	5	26	0. 0905	5	46	0. 0960
5	7	0. 0852	5	27	0. 0908	5	47	0. 0963
5	8	0. 0855	5	28	0. 0910	5	48	0. 0966
5	9	0. 0858	5	29	0. 0913	5	49	0. 0969
5	10	0. 0860	5	30	0. 0916	5	50	0. 0971
5	11	0. 0863	5	31	0. 0919	5	51	0. 0974
5	12	0. 0866	5	32	0. 0921	5	52	0. 0977
5	13	0. 0869	5	33	0. 0924	5	53	0. 0980
5	14	0. 0871	5	34	0. 0927	5	54	0. 0983
5	15	0. 0874	5	35	0. 0930	5	55	0. 0985
5	16	0. 0877	5	36	0. 0933	5	56	0. 0988
5	17	0. 0880	5	37	0. 0935	5	57	0. 0991
5	18	0. 0883	5	38	0. 0938	5	58	0. 0994
5	19	0. 0885	5	39	0. 0941	5	59	0. 0996

Elliot Lake Laboratory, Mines Branch, E. M. R.

CONVERTING TABLE From 6 to 7 minutes

Exposure Time in min	sec	converting in hours	Exposure Time in min	sec	converting in hours	Exposure Time in min	sec	converting in hours
6	0	0. 1000	6	20	0. 1055	6	40	0. 1111
6	1	0. 1002	6	21	0. 1058	6	41	0. 1113
6	2	0. 1005	6	22	0. 1061	6	42	0. 1116
6	3	0. 1008	6	23	0. 1063	6	43	0. 1119
6	4	0. 1011	6	24	0. 1066	6	44	0. 1122
6	5	0. 1013	6	25	0. 1069	6	45	0. 1125
6	6	0. 1016	6	26	0. 1072	6	46	0. 1127
6	7	0. 1019	6	27	0. 1075	6	47	0. 1130
6	8	0. 1022	6	28	0. 1077	6	48	0. 1133
6	9	0. 1025	6	29	0. 1080	6	49	0. 1136
6	10	0. 1027	6	30	0. 1083	6	50	0. 1138
6	11	0. 1030	6	31	0. 1086	6	51	0. 1141
6	12	0. 1033	6	32	0. 1088	6	52	0. 1144
6	13	0. 1036	6	33	0. 1091	6	53	0. 1147
6	14	0. 1038	6	34	0. 1094	6	54	0. 1150
6	15	0. 1041	6	35	0. 1097	6	55	0. 1152
6	16	0. 1044	6	36	0. 1100	6	56	0. 1155
6	17	0. 1047	6	37	0. 1102	6	57	0. 1158
6	18	0. 1050	6	38	0. 1105	6	58	0. 1161
6	19	0. 1052	6	39	0. 1108	6	59	0. 1163

Elliot Lake Laboratory, Mines Branch, E. M. R.

CONVERTING TABLE

From 1 to 60 minutes

Exposure Time		Exposure Time		Exposure Time	
in minutes	in hours	in minutes	in hours	in minutes	in hours
1	0. 0166	21	0. 3500	41	0. 6833
2	0. 0333	22	0. 3666	42	0. 7000
3	0. 0500	23	0. 3833	43	0. 7166
4	0. 0666	24	0. 4000	44	0. 7333
5	0. 0833	25	0. 4166	45	0. 7500
6	0. 1000	26	0. 4333	46	0. 7666
7	0. 1166	27	0. 4500	47	0. 7833
8	0. 1333	28	0. 4666	48	0. 8000
9	0. 1500	29	0. 4833	49	0. 8166
10	0. 1666	30	0. 5000	50	0. 8333
11	0. 1833	31	0. 5166	51	0. 8500
12	0. 2000	32	0. 5333	52	0. 8666
13	0. 2166	33	0. 5500	53	0. 8833
14	0. 2333	34	0. 5666	54	0. 9000
15	0. 2500	35	0. 5833	55	0. 9166
16	0. 2666	36	0. 6000	56	0. 9333
17	0. 2833	37	0. 6166	57	0. 9500
18	0. 3000	38	0. 6333	58	0. 9666
19	0. 3166	39	0. 6500	59	0. 9833
20	0. 3333	40	0. 6666	60	1. 0000

Elliot Lake Laboratory, Mines Branch, E. M. R.

APPENDIX D

AN EXAMPLE OF A PRACTICAL MEASUREMENT

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Plant-Noise Survey Form

DATE: 13/02/73
METER #: 2205 B&K

LOCATION: DENISON MINES LTD.
UNDERGROUND CRUSHER

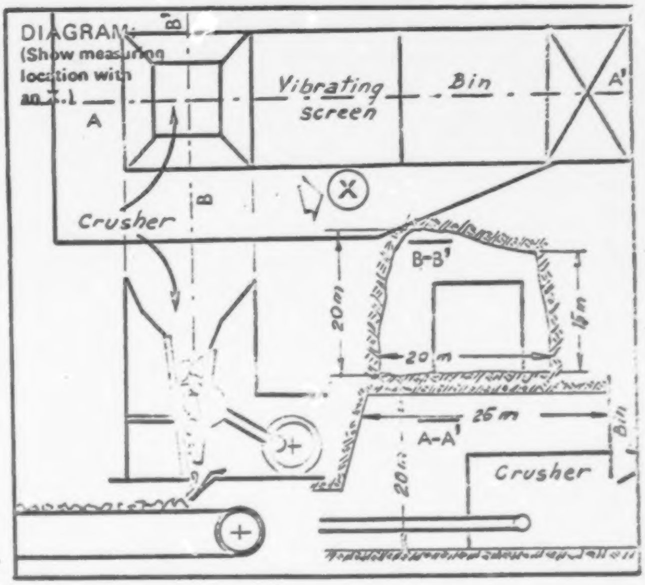
NUMBER OF PERSONNEL EXPOSED:

WEARING EAR PROTECTION? ☐ yes ☒ no

OPERATOR: M. SAVICH, W. STEFANICH

Equipment JAW CRUSHER
Manufacture
Steel type
Length (m.)
Bit type
Muffler type
Air kPa
Water kPa
Airflow m³/min.
Blow rate (blow/min.)
Penetration m./min.
Rock type URANIFEROUS CONGLOMERATE

DIAGRAM: (Show measuring location with an X.)

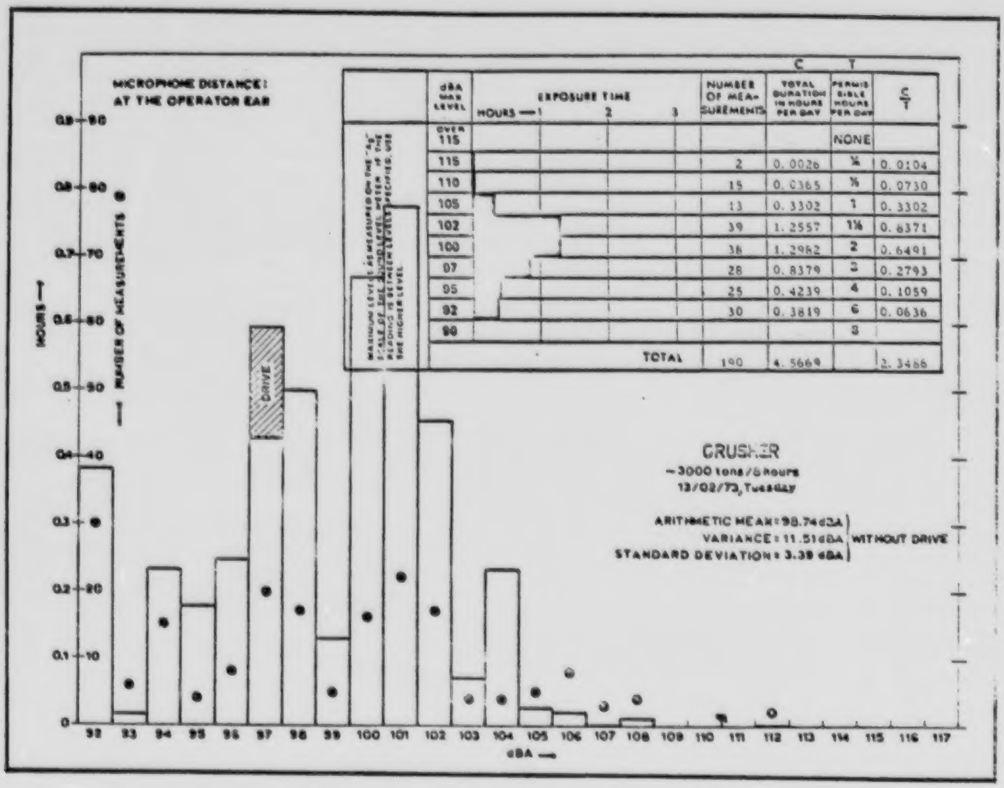


NOTES: MEASUREMENTS TAKEN AT CRUSHER OPERATOR CONTROL PANEL (EAR LEVEL) MOST OF ORE FROM ORE PASS.

	dBA MAX LEVEL	EXPOSURE TIME If necessary, note time of day	C TOTAL DURATION IN HOURS PER DAY	T PERMISSIBLE HOURS PER DAY	C/T
MAXIMUM LEVELS AS MEASURED ON THE "A" SCALE OF THE SOUND LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.	OVER 115			NONE	
	115	0.0026	0.0026	¼	0.104
	110	0.0195 + 0.0053 + 0.0117	0.0365	½	0.073
	105	0.0705 + 0.2332 + 0.0265	0.3302	1	0.033
	102	0.7753 + 0.4804	1.2557	1½	0.837
	100	0.4998 + 0.1296 + 0.6688	1.2982	2	0.649
	97	0.2455 + 0.4258 + 0.1666 (DRIVING)	0.8379	3	0.279
	95	0.0161 + 0.2317 + 0.1761	0.4239	4	0.106
	92	0.3891	0.3891	6	0.064
	90			8	
	UNDER 90			ANY	0
IMPACT CHECK MUST BE UNDER 140 dB PEAK SOUND PRESSURE LEVEL AS MEASURED WITH AN IMPACT NOISE ANALYZER OR BE UNDER 125 dB AS MEASURED WITH A SOUND LEVEL METER ON C WEIGHTING, FAST RESPONSE, 140 dB FULL SCALE RANGE.		MAX - 0 dB(C)		TOTAL To comply with regulations, total cannot be more than 1.	2.35

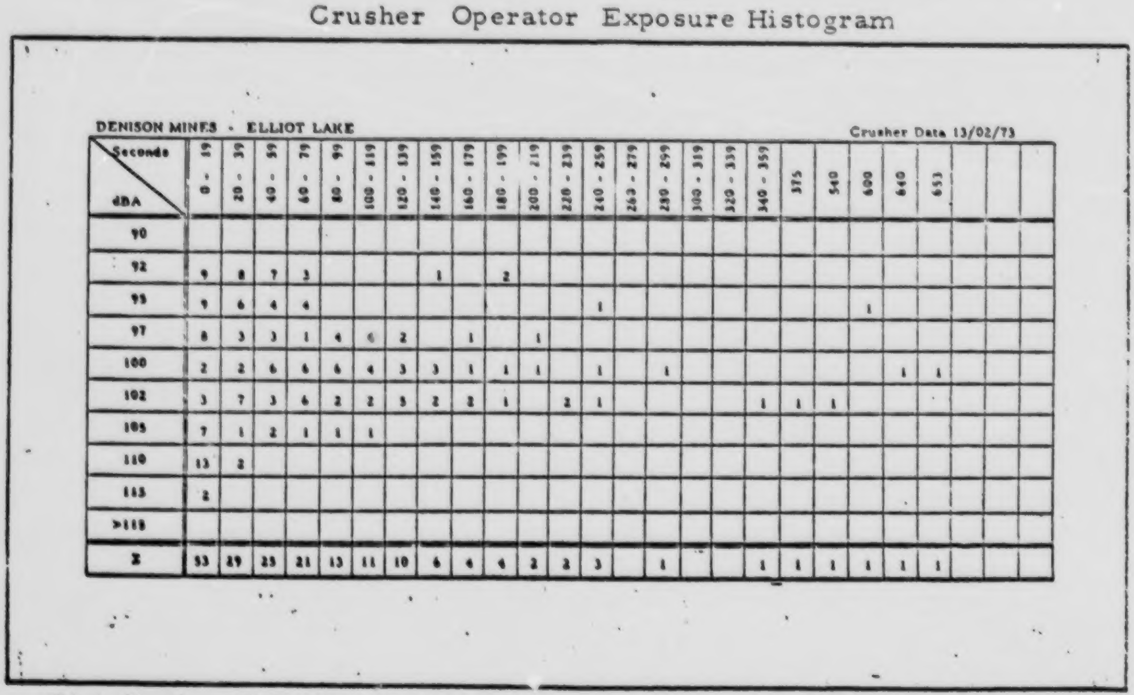
RECOMMENDATIONS: CRUSHER OPERATOR SHOULD WEAR EAR MUFFS.

SIGNED: Miray Savich



	dBA MAX LEVEL	EXPOSURE TIME HOURS — 1	2	3	NUMBER OF MEA-SUREMENTS	C TOTAL DURATION IN HOURS PER DAY	T PERMISSIBLE HOURS PER DAY	C/T
MAXIMUM LEVELS AS MEASURED ON THE "A" SCALE OF THE SOUND LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL	OVER 115						NONE	
	115				2	0.0026	¼	0.0104
	110				15	0.0365	½	0.0730
	105				13	0.3302	1	0.3302
	102				39	1.2557	1½	0.8371
	100				38	1.2982	2	0.6491
	97				28	0.8379	3	0.2793
	95				25	0.4239	4	0.1059
	92				30	0.3819	6	0.0636
	90						8	
	TOTAL				190	4.5669		2.3466

Crusher Operator Exposure Histogram



DENISON MINES - ELLIOT LAKE

Crusher Data 13/02/73

dBA \ Seconds	0 - 19	20 - 39	40 - 59	60 - 79	80 - 99	100 - 119	120 - 139	140 - 159	160 - 179	180 - 199	200 - 219	220 - 239	240 - 259	260 - 279	280 - 299	300 - 319	320 - 339	340 - 359	375	540	600	640	653			
90																										
92	9	8	7	3				1		2																
95	9	6	4	4									1								1					
97	8	3	3	1	4	6	2		1		1															
100	2	2	6	6	6	4	3	3	1	1	1		1		1							1	1			
102	3	7	3	6	2	2	5	2	2	1		2	1					1	1	1						
105	7	1	2	1	1	1																				
110	13	2																								
115	2																									
>115																										
Σ	53	29	25	21	13	11	10	6	4	4	2	2	3		1			1	1	1	1	1	1			

Distribution of A-Weighted Sound Level of Crusher Noises Sorted into Groups of Duration Times.

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Noise Survey Form (CONVERTING FORM)

DATE : 13/02/73
METER #: 2205 B&K
SHEET : 1

No.	dBA		No.	dBA		No.	dBA		No.	dBA		No.	dBA		No.	dBA	
	secs	hours		secs	hours		secs	hours		secs	hours		secs	hours		secs	hours
	92	dBA	22	36	0.0100	2	40	0.0111		96	dBA	11	95	0.0263	10	55	0.0152
1	155	0.0430	23	57	0.0158	3	40	0.0111	1	653	0.1824	12	177	0.0491	11	23	0.0063
2	183	0.0508	24	48	0.0133	4	60	0.0166	2	83	0.0229	13	52	0.0144	12	80	0.0221
3	13	0.0036	25	51	0.0141	5	73	0.0202	3	105	0.0291	14	60	0.0166	13	299	0.0830
4	11	0.0030	26	34	0.0094	6	58	0.0161	4	7	0.0019	15	105	0.0291	14	105	0.0291
5	42	0.0116	27	5	0.0013	7	64	0.0177	5	5	0.0013	16	95	0.0263	15	95	0.0263
6	30	0.0083	28	5	0.0013	8	31	0.0086	6	4	0.0011	17	120	0.0333	16	150	0.0416
7	60	0.0166	29	195	0.0541	9	45	0.0125	7	10	0.0027	18	15	0.0041	17	100	0.0277
8	63	0.0174	30	58	0.0161	10	27	0.0075	8	15	0.0041	19	30	0.0083			0.4998
9	20	0.0055			0.3891	11	37	0.0102			0.2455	20	25	0.0069			
10	5	0.0013				12	26	0.0072						0.4258		99	dBA
11	4	0.0011		93	dBA	13	14	0.0038		97	dBA				1	75	0.0207
12	5	0.0013	1	20	0.0055	14	65	0.0179	1	120	0.0333		98	dBA	2	53	0.0147
13	37	0.0102	2	5	0.0013	15	242	0.0671	2	51	0.0141	1	50	0.0138	3	120	0.0333
14	13	0.0036	3	13	0.0036			0.2317	3	48	0.0133	2	135	0.0374	4	80	0.0221
15	30	0.0083	4	3	0.0008				4	25	0.0069	3	170	0.0471	5	140	0.0388
16	27	0.0075	5	7	0.0019		95	dBA	5	90	0.0249	4	75	0.0207			0.1296
17	15	0.0041	6	11	0.0030	1	600	0.1666	6	105	0.0291	5	61	0.0168			
18	69	0.0191			0.0161	2	25	0.0069	7	206	0.0575	6	184	0.0511		100	dBA
19	45	0.0125				3	25	0.0013	8	10	0.0027	7	126	0.0348	1	75	0.0207
20	42	0.0116		94	dBA	4	5	0.0013	9	7	0.0019	8	42	0.0116	2	8	0.0022
21	22	0.0061	1	15	0.0041			0.1761	10	100	0.0277	9	55	0.0152	3	640	0.2777

LOCATION: UNDERGROUND CRUSHER (DENISON MINE)

OPERATOR: Azirag Sawick and [illegible]

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Noise Survey Form (CONVERTING FORM)

DATE : 13/02/73
METER #: 2205 B&K
SHEET : 2

No.	dBA		No.	dBA		No.	dBA		No.	dBA		No.	dBA		No.	dBA	
	secs	hours		secs	hours		secs	hours		secs	hours		secs	hours		secs	hours
4	89	0.0246	7	220	0.0611	4	58	0.0161		104	dBA	7	5	0.0013		DRIVING	
5	115	0.0318	8	240	0.0666	5	221	0.0613	1	4	0.0011	8	3	0.0008		97	dBA
6	153	0.0424	9	41	0.0113	6	341	0.0946	2	5	0.0013			0.0195	1	300	0.0833
7	104	0.0288	10	100	0.0277	7	120	0.0333	3	50	0.0138				2	300	0.0833
8	246	0.0685	11	61	0.0168	8	34	0.0094	4	20	0.0055		107	dBA			0.1666
9	70	0.0193	12	10	0.0027	9	20	0.0055			0.2332	1	5	0.0013			
10	90	0.0249	13	20	0.0055	10	37	0.0102				2	5	0.0013			
11	43	0.0119	14	30	0.0083	11	25	0.0069		105	dBA	3	10	0.0027			
12	90	0.0249	15	75	0.0207	12	150	0.0416	1	5	0.0013			0.0053			
13	30	0.0083	16	25	0.0069	13	85	0.0235	2	70	0.0193						
14	211	0.0588	17	17	0.0047	14	65	0.0179	3	7	0.0019		108	dBA			
15	75	0.0207	18	110	0.0304	15	55	0.0152	4	10	0.0027	1	25	0.0069			
16	12	0.0033	19	131	0.0363	16	120	0.0333	5	5	0.0013	2	5	0.0013			
		0.6688	20	150	0.0416	17	10	0.0027			0.0265	3	3	0.0008			
			21	65	0.0179			0.4804				4	10	0.0027			
	101	dBA	22	60	0.0166					106	dBA			0.0117			
1	120	0.0333			0.7753		103	dBA	1	20	0.0055						
2	195	0.0541				1	90	0.0249	2	6	0.0016		112	dBA			
3	375	0.1041		102	dBA	2	15	0.0041	3	15	0.0041	1	5	0.0013			
4	120	0.0333	1	160	0.0444	3	50	0.0138	4	5	0.0013	2	5	0.0013			
5	92	0.0254	2	67	0.0185	4	100	0.0277	5	5	0.0013			0.0026			
6	540	0.1500	3	166	0.0460			0.0705	6	13	0.0036						

LOCATION: UNDERGROUND CRUSHER (DENISON MINE)

OPERATOR: Antony Sauck and Wm. Stefanick

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Noise Survey Form

MAXIMUM LEVELS AS MEASURED ON THE "As" SCALE OF THE SOUND LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.

DATE: 13/02/73
METER #: 2205 B&K
SHEET: 1

No.	EXPOSURE		NOTES	No.	EXPOSURE		NOTES	No.	EXPOSURE		NOTES
	TIME	dBA			TIME	dBA			TIME	dBA	
	7:30 h		NO. 2 SHAFT.	22	0:25	108		46	1:15	98	Λ 104-106
1	5:00*	97	*TIME IN MIN. DRIVING	23	3:27	97		47	1:15	100	
2	2:40	102		24	1:32	101		48	2:57	97	
3	2:00	101		25	9:00	101		49	10:57	96	
4	2:00	97		26	0:20	106		50	0:25	95	
5	0:50	98		27	0:10	97		—	∝	<90	10:30 h
6	0:20	93		—	2:00	<90		51	0:20	92	
7	3:15	101		28	0:13	92		52	1:04	94	
8	0:15	94		29	3:40	101		53	0:52	97	
9	6:15	100		30	2:15	98		54	0:10	101	
—	∝	<90		31	4:00	101		55	0:05	92	
10	0:50	97		32	0:58	94		—	∝	<90	10:41 h
11	0:40	94		—	∝	<90		56	0:08	100	
12	0:48	97		33	0:11	92		57	1:23	96	
—	∝	<90		—	∝	<90		58	1:00	97	
13	2:35	92		34	0:07	97		59	0:04	92	
14	0:25	97		35	1:40	97		—	∝	<90	10:45 h
—	∝	<90		36	0:05	108		60	0:05	93	
15	0:40	94		37	0:41	101		61	0:31	94	
16	1:30	97		38	0:42	92		—	∝	<90	
—	∝	<90		39	1:40	101		62	1:45	97	
17	1:45	97		40	0:30	92		63	0:20	101	
18	3:07	92		41	1:35	97		64	0:05	92	
19	1:10	94		42	1:00	92		—	∝	<90	
—	∝	<90		43	1:10	101		65	1:30	103	
20	1:13	94		44	2:50	98	Λ 108	66	0:05	112	
21	2:00	101		45	1:03	92	PEAK	67	1:35	97	

OPERATOR:
WM. STEFANICH

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Noise Survey Form

MAXIMUM LEVELS AS MEASURED ON THE "As" SCALE OF THE SOUND LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.

DATE: 13/02/73
METER #: 2205 B&K
SHEET: 2.

No.	EXPOSURE		NOTES
	TIME	dBA	
68	0:05	105	
69	0:37	92	
70	1:10	98	
71	0:45	94	
72	0:13	92	
73	0:30	101	
74	0:30	92	
—	∝	< 90	
75	0:27	92	
—	∝	< 90	
76	0:15	92	
—	∝	< 90	
77	3:04	98	
78	1:09	92	
79	1:07	102	
80	2:05	98	
81	0:45	92	
82	0:42	98	
83	0:42	92	
—	∝	< 90	
84	2:46	102	
85	0:27	94	
86	16:40	100	
87	0:22	92	
88	1:29	100	
89	0:36	92	
90	0:58	102	

No.	EXPOSURE		NOTES
	TIME	dBA	
91	0:37	94	
92	1:55	100	
93	0:26	94	
94	2:33	100	
95	0:57	92	
96	3:41	102	
97	1:44	100	
98	0:48	92	
99	4:07	100	
100	0:51	92	
101	1:10	100	
102	0:05	106	
103	5:41	102	
104	1:30	100	12:38 h
105	0:14	94	
106	0:43	100	
107	0:34	92	
108	2:00	102	
109	2:00	97	
110	1:30	100	
111	1:15	101	
112	1:15	99	
113	1:10	105	∧ 108
114	0.05	92	
	∝	< 90	12:50 h
115	0.04	104	
116	0:15	106	

No.	EXPOSURE		NOTES
	TIME	dBA	
117	0:34	102	
118	0:05	107	
119	0:25	101	
120	0:15	97	
—	∝	< 90	
121	0:05	104	SCOOPTRAM
—	∝	< 90	
122	0:07	105	
123	0:55	98	
124	1:05	94	92 - 95
—	∝	< 90	13:08 h
125	0:05	106	
126	1:45	96	
—	∝	< 90	
127	0:05	92	
—	∝	< 90	
128	0:53	99	
129	3:15	92	
130	0:30	97	
131	2:00	99	98 - 99
132	0:30	100	
—	∝	< 90	
133	3:32	100	96 - 104
134	0:05	107	TELETRAM
135	4:02	94	
—	∝	< 90	13:37 h
136	0:03	104	REAR - DUMP TRUCK.

OPERATOR: ....
WM. STEFANICH

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VoL.1 Report 2

73-108 M. Savich and W. Stefanich

Developement of a standard method for testing noise exposure

1973

Nouvelle méthode graphique pour l'évaluation de l'exposition au bruit

par

Miron Savich*

RÉSUMÉ

Pour évaluer et prévoir l'exposition au bruit dans les mines, il convient de disposer d'une méthode utilisable par des personnes sans formation technique particulière en acoustique.

Nous avons donc mis au point une nouvelle méthode graphique d'évaluation de l'exposition au bruit. Avec cette méthode, on utilise le planimètre ordinaire pour évaluer le niveau de bruit moyen et un nouvel intégrateur mécanique pour évaluer l'exposition au bruit. Il n'est pas nécessaire de disposer d'un matériel de mesures acoustiques complexe ou d'un ordinateur.

Sont inclus deux exemples de mesures pratiques montrant comment les méthodes peuvent être appliquées simplement pour un contrôle personnel, administratif et technique dans les mines, les usines, le réseau routier ou l'armée. La nouvelle méthode est simple, rapide et peu coûteuse. Elle convient parfaitement pour les mines canadiennes.

Exposition au bruit : Méthode graphique : Planimètre : Intégrateur mécanique : Mines

* Chercheur, Laboratoire d'Elliot Lake, Laboratoires de recherche minière, Direction des mines, ministère de l'Énergie, des Mines et des Ressources, Elliot Lake (Ontario).

A New Graphical Method for the Evaluation of Noise Exposure

by

Miron Savich*

- - - - - - - -

ABSTRACT

For making assessments of present and predicted noise exposure in mines, a procedure is required that can be used by persons who do not have technical training in acoustics.

For this reason, a new graphical method for evaluation of noise exposure was developed. It uses the standard planimeter for evaluation of mean noise level and a newly constructed mechanical integrator for evaluation of noise exposure. Sophisticated acoustical measurement equipment and a computer are not required.

Two examples of a practical measurement are included showing how the procedures can be simply applied for personal, administrative and engineering control of all conditions in mines, factories, traffic or in military applications. The new method is simple, fast and inexpensive to apply in Canadian mines.

Noise exposure: Graphical method: Planimeter: Mechanical integrator: Mines

* Research Scientist, Elliot Lake Laboratory, Mining Research Centre, Mines Branch, Department of Energy, Mines and Resources, Elliot Lake, Ontario.

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TABLE

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APPENDICES

Appendix A

Mechanical Integrator 1

Appendix B

Plant-Noise Survey Form, 21/08/73 1
OSHA Noise Survey Form, 21/08/73 2
Crusher Operator Histogram, 21/08/73 4

Appendix C

Plant-Noise Survey Form, 22/08/73 1
OSHA Noise Survey Form, 22/08/73 2
Crusher Operator Histogram, 22/08/73 4

1. INTRODUCTION

After a few years of experience with the application of standards contained in the U.S. Walsh-Healey Act and OSHA*, more and more mining engineers are raising questions about the problems associated with the act, the way it is being implemented, and the high cost of compliance (1).

Some OSHA regulations are so unclear that many environmental engineers are confused as to what is required. Sometimes they are confused even when the regulations are clear (2). One aspect of this situation is the confusion concerning the assessment of environmental noise exposure in mines. The present paper offers a solution that corresponds most to the needs of large and small mines, is simple and clear and offers maximum profit, and is acceptable to employees, employee unions, and safety directors of both the company and government.

2. NOISE MEASUREMENT

2.1 Occupational Noise Exposure

The objective of the study is to identify the Noise Exposure Index. The permissible noise exposures are given in Table 1. When the noise consists of different levels throughout the day, their combined effect is considered as follows:

$$\Sigma^{C}/T = (C_A/8 + C_B/6 + C_C/4 + C_D/3 + C_E/2 + \ldots + C_J/0.25) \quad \text{(Equation 1)}$$

where $\Sigma^{C}/T \leq 1$ is the OSHA Mixed Exposure Index, and C_A is the total time

---

* The Occupational Safety and Health Act.

TABLE 1

Noise Exposure Limits for a Normal 8-Hour Working Day

Band	Noise Level	Maximum Exposure
A	90 dBA	8 hours
B	90 to 92 "	6 "
C	92 to 95 "	4 "
D	95 to 97 "	3 "
E	97 to 100 "	2 "
F	100 to 102 "	1.5 "
G	102 to 105 "	1 "
H	105 to 110 "	0.5 "
J	110 to 115 "	0.25 "
	Above 115 "	None

the noise level is in band A, C_B is the total time the noise level is in band B, etc. These limits are based on tests showing that, for every halving of the duration of exposure, the intensity of exposure can be increased 5 dBA without an increase in the risk of noise-induced hearing losses.

The A-, B-, and C-weighting networks were designed to approximate the loudness-level sensitivity of the human ear when listening to pure tones. The A-weighted reading is used to estimate the probability of hearing damage in industry. The B-weighting network is rarely used, and the C-weighting network is used to limit the low- and high-frequency response of the instrument.

2.2 Equipment

A sound level meter is the basic instrument for noise measurement and for measuring noise exposure. A general-purpose sound level meter shall cover the frequency range 315 to 8000 Hz and shall include the three different response curves, A, B, and C. The microphone shall be omnidirectional. Sound level meters may also be used for measurement in terms of A-weighted sound level.

Noise dose meters automatically integrate the sound energy received, allowing simple calculation of equivalent continuous sound level. Noise dose meters may be a great advantage when making measurements to determine excessive noise exposure. They are a recent development.

Graphic level recorders provide a permanent graphic record of the sound level which can be analyzed statistically to determine the noise exposure index. It is possible to carry out a statistical analysis of the record manually, but this process takes time (3). For this reason, in the present situation, it is more convenient to use a statistical analyzer (4).

A magnetic tape recorder is useful to record fluctuating sounds for later analysis in a laboratory, but this equipment is very expensive.

These claims for the noise measuring systems show that some appreciably more complex and specialized systems than a sound level meter have been developed for this purpose.

3. PROCEDURES FOR MAKING ASSESSMENTS OF THE NOISE EXPOSURE INDEX

3.1 Evaluation of Mean Noise Level with Planimeter

The arithmetic mean of a set of N numbers, X_1, X_2, X_3, ..., X_N is denoted by $\bar{X}$ and is defined as:

$$\bar{X} = \frac{X_1 + X_2 + X_3 + \ldots + X_N}{N} = \frac{\sum_{j=1}^{N} X_j}{N} = \frac{\Sigma X}{N} \qquad \text{(Equation 2)}$$

If the numbers X_1, X_2, ..., X_K occur with frequencies f_1, f_2, ..., f_K, the arithmetic mean is:

$$\bar{X} = \frac{f_1 X_1 + f_2 X_2 + \ldots + f_K X_K}{f_1 + f_2 + \ldots + f_K} = \frac{\sum_{j=1}^{K} f_j X_j}{\sum_{j=1}^{K} f_j} = \frac{\Sigma fX}{\Sigma f} = \frac{\Sigma fX}{N} \qquad \text{(Equation 3)}$$

if the f_j's are not all equal to 1, and $N = \Sigma f$ is the total number of cases. Graphically the arithmetic mean could be described as in Figure 1, and the value of $\bar{X}$ obtained from the following formula:

$$\bar{X} = \frac{\Sigma fX}{N} = \frac{k}{N} \qquad \text{(Equation 4)}$$

where k = area,

N and $\bar{X}$ = coordinates.

In our case, N is the total number of time periods and $\bar{X}$ is the mean noise level, if the noise never drops below the base level. If we apply this on paper tapes from a graphic level recorder with A-weighted sound level, 90 dBA base line (or 85 dBA as the new standard requires), we obtain

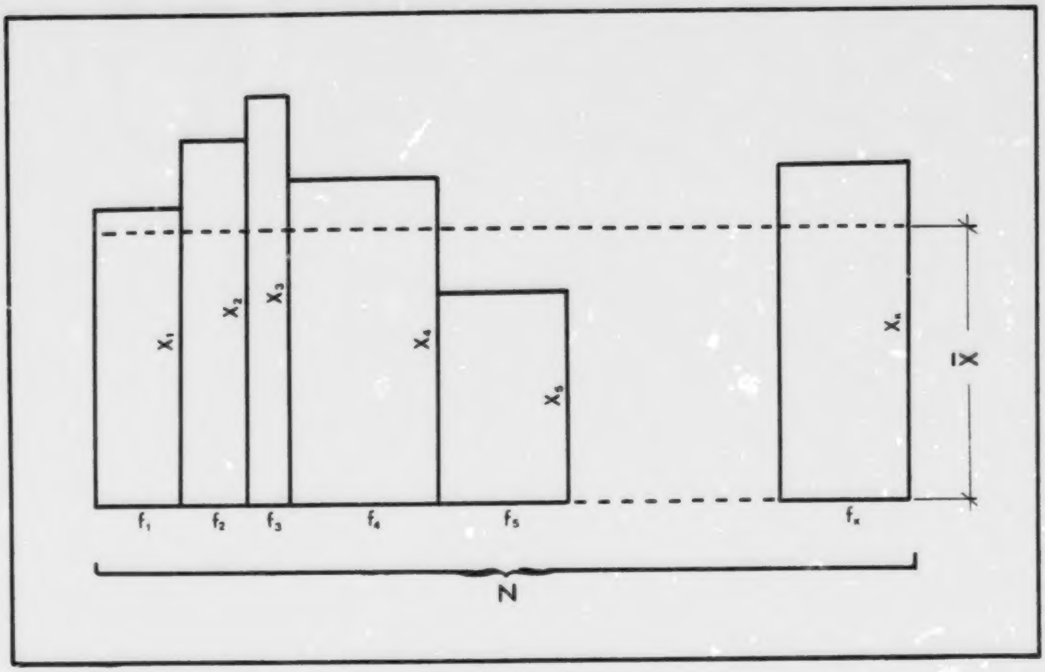

FIGURE 1: Graphic Description of the Arithmetic Mean.

the average noise indirectly, as shown in Figure 2-1 and 2-2.

We always calculate with relative values to obtain the absolute value. The evaluation procedure is as follows:

1. The average levels on paper tape are estimated and marked with a pencil.
2. The base line is determined by the standard or act.
3. Over the base line the surfaces are evaluated with the planimeter in cm^2 (3.2 cm^2) (Figure 2-2).
4. The evaluated surface is divided by the exposure time in cm (7.6 cm) according to Equation 4.

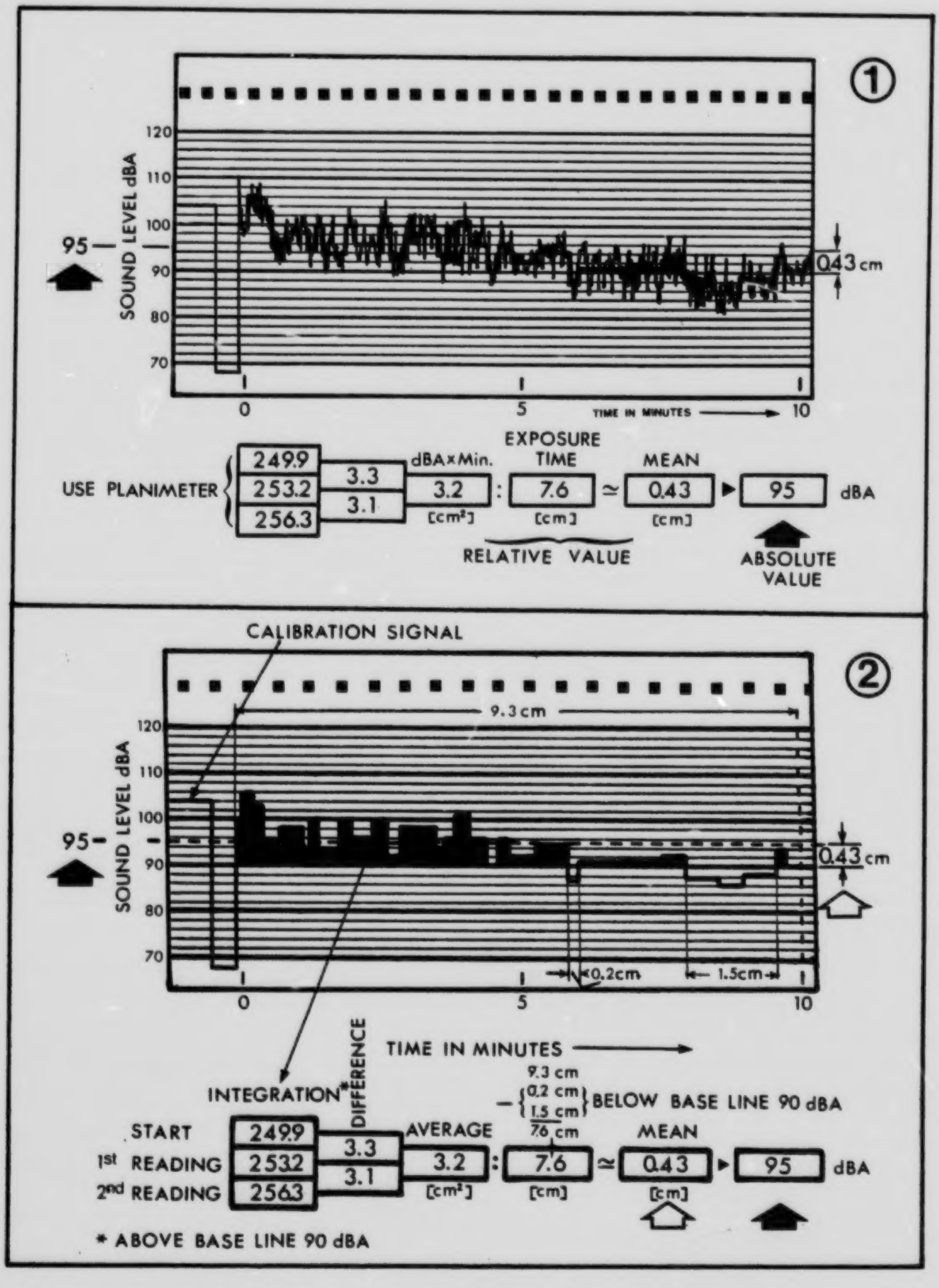

FIGURE 2: Evaluation of Mean Noise Level from the Graphic Level Recorder with Planimeter. 1. General, 2. In Detail.

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5. The relative value obtained is transferred above the base line (0.43 cm).
6. The mean sound level, 95 dBA, is automatically obtained from the sound level scale.

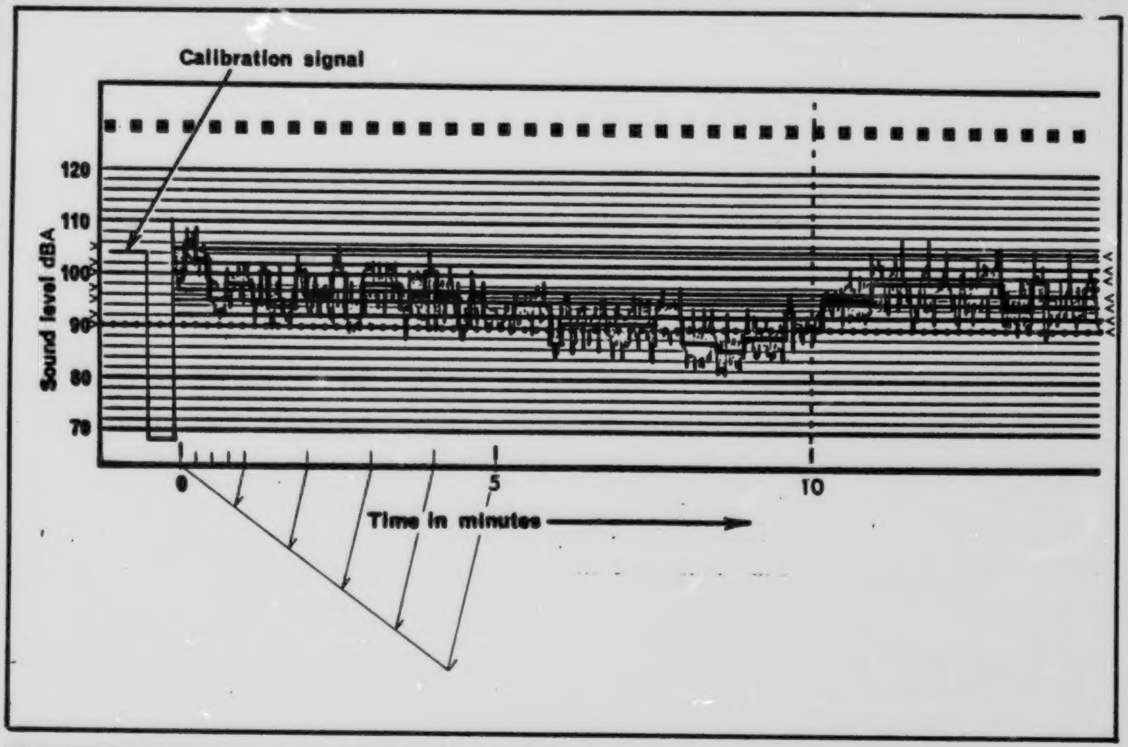
This method is used when dBA is expressed in a linear scale.

3.2 Evaluation of Noise Exposure with Mechanical Integrator

For evaluation of noise exposure the mechanical integrator is used (Appendix A). The evaluation procedure is as follows (Figure 3):

1. The average levels on paper tape are estimated and marked with a pencil.
2. The base line is determined by the standard or act.
3. The lines of permissible noise levels according to the standard or act are drawn parallel to the base line with a colored pencil.
4. With the mechanical integrator, the total time for which the noise level is at each selected value, 90, 92, ..., 115 dBA, is integrated step by step (Figure 4). If the reading is between levels specified, use the higher level. Total duration time is expressed in minutes.
5. The values are transferred to the table of Figure 3 and the evaluation is made according to the Walsh-Healey or OSHA exposure limits (Table 1).

This method is used when dBA is expressed in a linear or logarithmic scale.



TIME \ dBA	90	92	95	97	100	102	105	110	115	>115			TOTAL TIME
										120	125	130	
C TOTAL DURATION IN MINUTES	0.50	2.70	1.70	1.20	1.70	0.15	0.15	0.15	—	—	—	—	8.25
T PERMISSIBLE MINUTES PER DAY	480	360	240	180	120	90	60	30	15	NONE			EXPOSURE INDEX $\Sigma C/T$
C/T	0.001	0.0075	0.0071	0.0067	0.0142	0.0017	0.0025	0.005	—	—	—	—	0.046

FIGURE 3: Evaluation of Noise Exposure from the Graphic Level Recorder with Mechanical Integrator.

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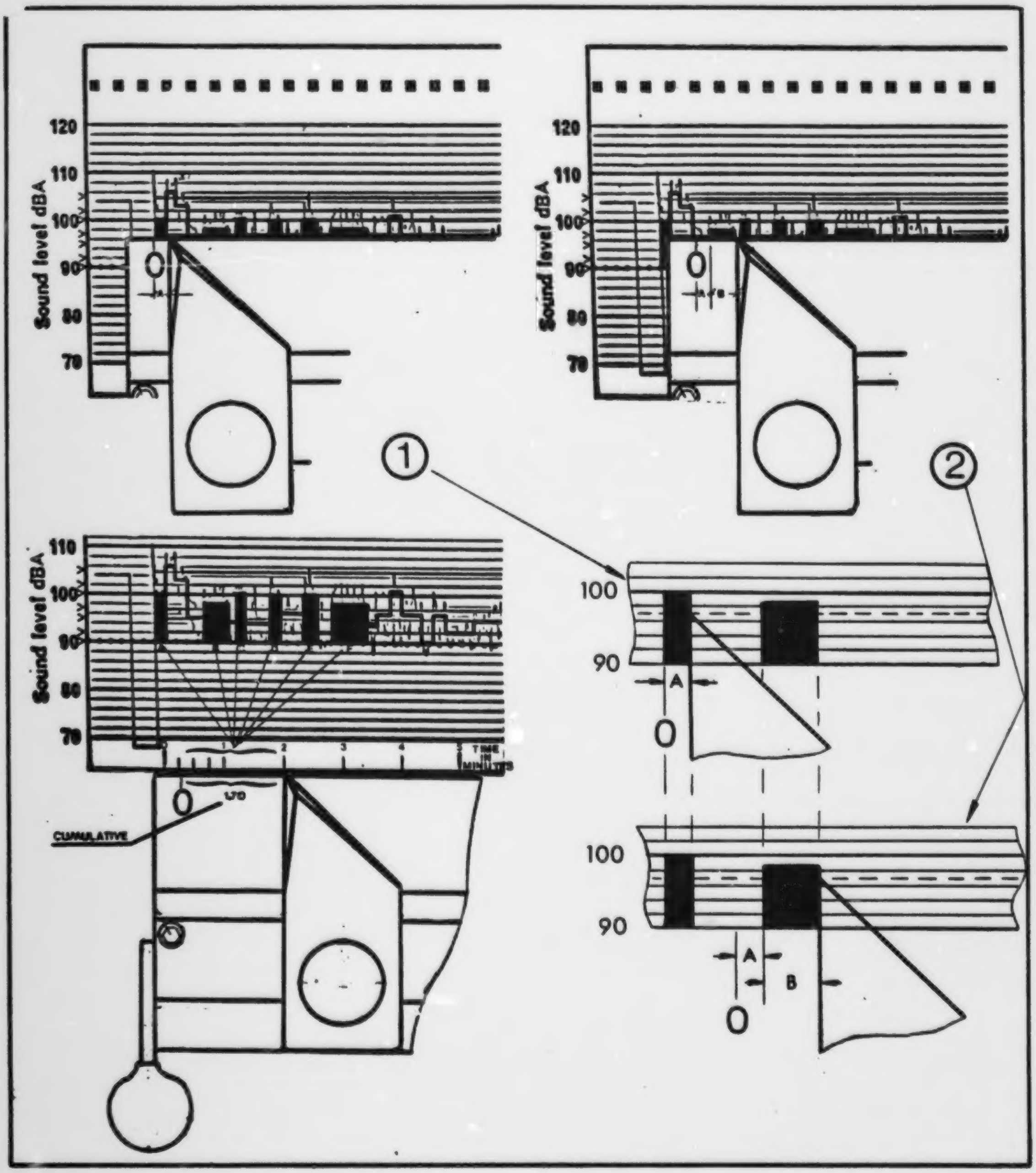
120
110
100
90
80
70
Sound level dBA
0
①
②
TIME IN MINUTES
1
2
3
4
5
CUMULATIVE
1.70
100
90
A
B
0

Figure 4: Using the Mechanical Integrator to determine cumulative Noise Exposure from a Graphic Level Recorder.

1) Choose a level (here 100 dBA).
   Place "0" of rule a first point, move slide to second point, as shown.
2) Move entire rule, to the right, until left edge of slide rests on the next point, etc.

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4. PRACTICAL APPLICATION

In the absence of a graphic level recorder we transformed the numerical data of noise levels of a jaw crusher into graphical data, to be able to show the advantage of the new evaluation methods. The error in the transformation is very small because the evaluation is performed with relative values (Appendix B, pp 4, 5, 6, and Appendix C, pp 4, 5, 6).

The measurement of the noise levels at the jaw crusher operator's control panel was performed with three instruments (Figure 5).

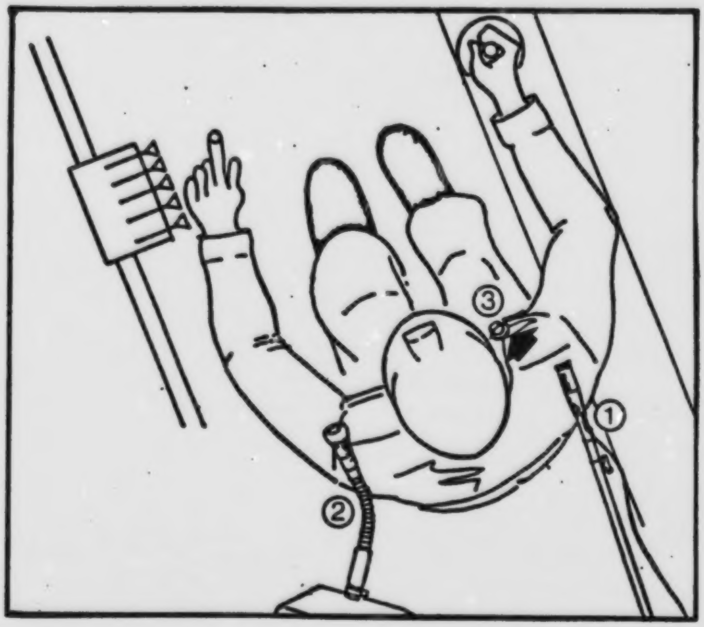

FIGURE 5: Measuring Noise Levels at the Crusher Operator's Control Panel (Ear Level) with Three Instruments.

1. Sound Level Meter (B and K*, Type 2205)
2. Noise Classifier (B and K, Model 166)
3. Dosimeter (Bendix, Model 1150)**

---

*Bruel and Kjaer, ** Noise Exposure Monitor (Bendix, Model 1150)

The jaw crusher exposures will not occur in a highly directional field, but somewhere between this and a diffuse field. Results from previous studies show that variations are insignificant in a diffuse field (5, 6).

The results obtained using a dosimeter with the microphone, in a free field, located on the top of the subject's shoulder, oriented parallel to the body, should be comparable with those obtained using the standard sound level meter (7).

Noise exposure indices at the crusher operator's ear were as follows (Appendix B, pp 1 to 6, Appendix C, pp 1 to 6):

Instrument	21/08/73		22/08/73	
	Exposure Index	%	Exposure Index	%
Sound Level Meter B and K, #2205	1.67	100	1.28	100
Noise Classifier B and K, #166	1.65	98.8	1.25	97.7
Sound Level Meter B and K, #2205 - Graphical Method -	1.62	97.0	1.27	99.2
Dosimeter Bendix, #1150	1.74	104.2	1.97	153.0

On the first day of measurement, 21/08/73, the results were almost the same. Unfortunately on the second day of measurements the dosimeter, Bendix Model 1150, indicated a 50% higher exposure index than the other instruments, probably because of high humidity affecting the instrument accuracy.

Average noise levels in dBA at the crusher operator's ear were calculated with a computer and graphical method as follows (Appendix B, pp 1 to 6, Appendix C, pp 1 to 6):

> 90 dBA	Sound Level Meter B and K, #2205		Sound Level Meter B and K, #2205 Graphical Method		Noise Classifier B and K, #166	
	21/08/73	22/08/73	21/08/73	22/08/73	21/08/73	22/08/73
Arithmetic Mean	97.9	97.6	99	98	98.7	98.95
Variance	16.12	16.5	--	--	17.8	17.1
Standard Deviation	4.01	4.06	--	--	4.22	4.14

The results are identical. This practically confirms that the application of the standard method for testing noise exposure, if the noise levels vary, with the universal attachment with holding and extension rods and microphone holder gives excellent results because the minimum time for a prescribed number of readings is 2 sec (5). The operator must not only measure more than one noise level, he must also time the duration of each level so the total combined noise exposure ($\Sigma\, ^{C}/T$) can be calculated.

5. CONCLUSION

For a definite solution of the evaluation of noise exposure with the new graphical method in mines, the following is proposed:

- for measuring noise in a mine, to use a light portable sound level meter with sound level recorder. The dBA scale should be linear but it is acceptable if it is logarithmic.

The advantages of the proposed methods are the following:

- The measurement technique is simple and the evaluation of the data is simplified and accessible to everyone.
- The accuracy of results is almost the same as with that obtained by numerical methods.
- It is possible to follow simultaneously:
    1. Personal protective control: it is very simple to find maximums from the diagram on the graphic level recorder and to determine the level of personal protection.
    2. Administrative control: it is possible to apply every risk criteria and to collect valuable data for the future determination of permissible conditions of exposure in mines.
    3. Engineering control gives new and until now unusual data. The control of regular and correct work of the crusher and its efficiency can be exercised through the diagram, as noise is a function of machine operating practice.
- The management will be interested in the measurement of noise in mines and in the new evaluation methods of noise exposure because it also gives important technical data.

Disadvantage:

- It is not applicable to single noise transients produced by the impact of industrial equipment such as large forges. Unfortunately, no firm criteria for protection against impulse noise have yet been established, and there are no adequate standard methods.

The new methods of evaluation of noise exposure are simple, fast, efficient, and can be applied to all conditions in Canadian mines.

6. ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Denison Mines Limited who provided the assistance for this project. A.C. Rickaby, General Mine Superintendent, participated in the development of the project. J.L. Chakravatti, Environmental Control Engineer, was helpful in many ways.

He acknowledges the contribution of G. Zahary, Manager, D.G.F. Hedley, G. Knight, and R. Tervo, Research Scientists, Elliot Lake Laboratory, and thanks J. Smith for his assistance in the design and construction of the mechanical integrator. W. Stefanich, technician, Elliot Lake Laboratory, and G. Morgan, student, Chemical Engineering, University of Waterloo, provided technical assistance.

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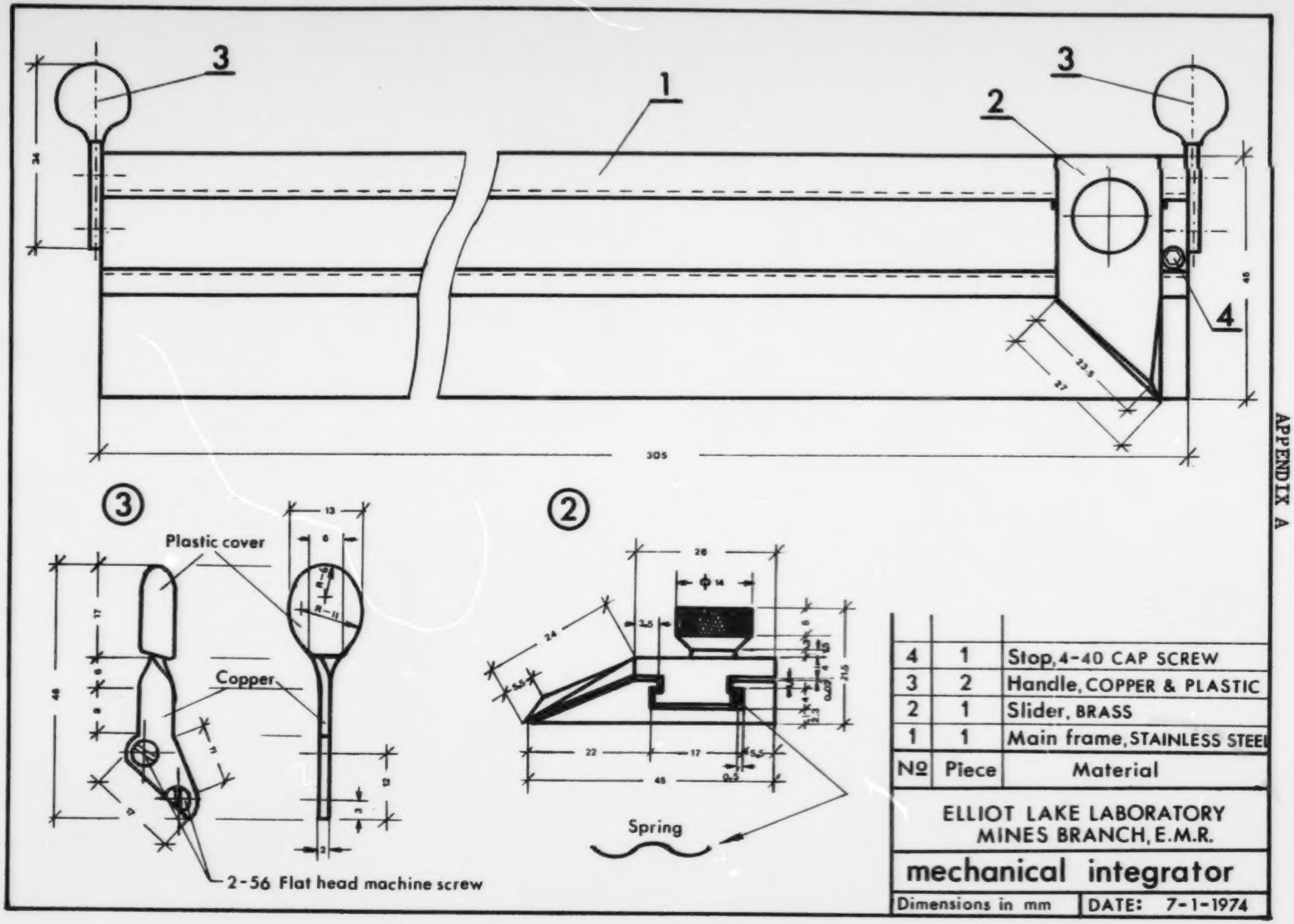
APPENDIX A


1
2
3
3
4
305
34
45
23.5
27
③
Plastic cover
Copper
2-56 Flat head machine screw
13
6
R-11
46
17
6
8
12
3
2
②
28
Φ14
3.5
24
5.5
22
17
45
21.5
0.5
Spring

Nº	Piece	Material
4	1	Stop, 4-40 CAP SCREW
3	2	Handle, COPPER & PLASTIC
2	1	Slider, BRASS
1	1	Main frame, STAINLESS STEEL

ELLIOT LAKE LABORATORY
MINES BRANCH, E.M.R.

mechanical integrator

Dimensions in mm DATE: 7-1-1974

APPENDIX B

ELLIOT LAKE LABORATORY, MINES BRANCH, EMR.

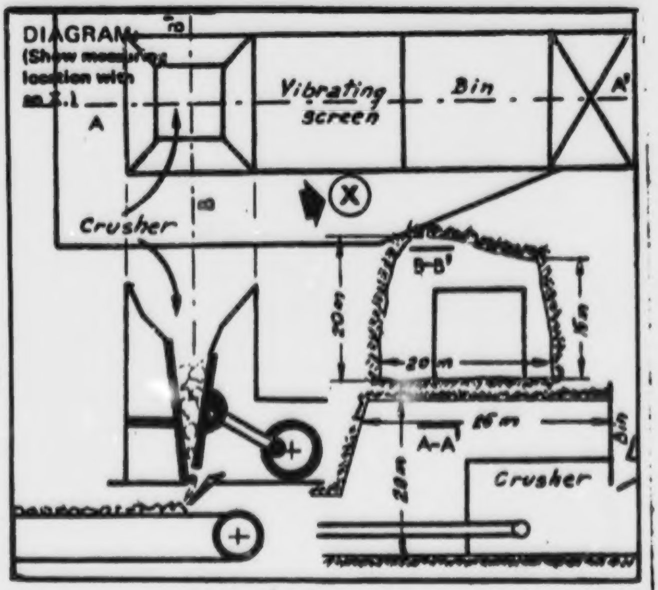
Plant-Noise Survey Form

DATE: 21-08-73
METER #: 2205 B&K

LOCATION: MINES LTD.
UNDERGROUND CRUSHER
NUMBER OF PERSONNEL EXPOSED:
WEARING EAR PROTECTION? ☒ yes ☐ no
OPERATOR: M. SAVICH

Equipment JAW CRUSHER.
Manufacture
Steel type
Length (m.)
Bit type
Muffler type
Air kPa
Water kPa
Airflow m^3/min.
Blow rate (blow/min).
Penetation m./min.
Rock type QUARTZ CONGLOMERATE

DIAGRAM: (Show measuring location with an X.)



NOTES: MEASUREMENTS TAKEN AT CRUSHER OPERATOR CONTROL PANEL (EAR LEVEL)

	dBA MAX LEVEL		C TOTAL DURATION IN HOURS PER DAY	T PERMISSIBLE HOURS PER DAY	C/T
MAXIMUM LEVELS AS MEASURED ON THE "A_S" SCALE OF THE SOUND-LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.	OVER 115			NONE	
	115			¼	
	110	0.0193 + 0.0041 + 0.0044	0.0280	½	0.06
	105	0.1852 + 0.1213 + 0.0005	0.3070	1	0.31
	102	0.1485 + 0.4625	0.6110	1½	0.41
	100	0.7944 + 0.1985 + 0.3682	1.3611	2	0.68
	97	0.0147 + 0.0458	0.0605	3	0.02
	95	0.1408 + 0.1166 + 0.0824	0.3398	4	0.08
	92	0.2685 + 0.3136	0.5821	6	0.10
	90	0.0179	0.0179	8	0.002
		Σ	3.3074		
IMPACT NOISE MUST BE UNDER 140 dB PEAK SOUND-PRESSURE LEVEL AS MEASURED WITH AN IMPACT NOISE ANALYZER, OR BE UNDER 120 dB AS MEASURED WITH A SOUND LEVEL METER ON C WEIGHTING, FAST RESPONSE, 140 dB FULL SCALE RANGE.		MAX - dB(C)		TOTAL To comply with regulations, total cannot be more than 1.	1.67

RECOMMENDATIONS:

SIGNED: Miroy Savich

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

OSHA
Noise Survey Form

B & K 166 Environmental Noise Classifier

Test must coincide with full work shift.

Date: 21/08/1973

Time from 8:00 A.M. to 3:40 P.M

Location: Mines Ltd.

Made by: Miron Savich

Instrument No. ______

Base Line set at 90 dB (normally 90) and Weighting Selector set at 90.

Total test time 482.6 minutes

EQUIPMENT TESTED(SEE OTHER SIDE FOR DETAILS): JAW CRUSHER

SHEET: 1

Exposure in Minutes

90 to 92 dBA	92 to 95 dBA	95 to 97 dBA	97 to 100 dBA	100 to 102 dBA	102 to 105 dBA	105 to 107 dBA	107 to 110 dBA	110 to 112 dBA	112 to 115 dBA	Over 115 dBA		Exposure Value (%)
										to 120	to 125	
480 420 360 300 240 180 120 60	320 280 240 200 160 120 80 40	240 210 180 150 120 90 60 30	160 140 120 100 80 60 40 20	120 110 100 90 80 70 60 50 40 30 20 10	80 70 60 50 40 30 20 10	60 50 40 30 20 10	40 35 30 25 20 15 10 5	30 25 20 15 10 5	20 15 10 5	Not Permissible		130 120 110 100 90 80 70 60 50 40 30 20 10
21.9	10.0	19.2	55.2	48.0	21.9	3.1	1.2	0.1	—	—	—	
6.3	4.0	10.0	45.5	55.0	35.5	6.0	3.0	~0	—			

1. Enter time in minutes from counters on the 166.
2. Enter Exposure Value (%) from right-hand column corresponding to minutes in table.
3. Add Exposure Values 165 = % Permissible Exposure
4. Divide % Permissible Exposure by 100 to obtain OSHA Mixed Exposure Index 1.65

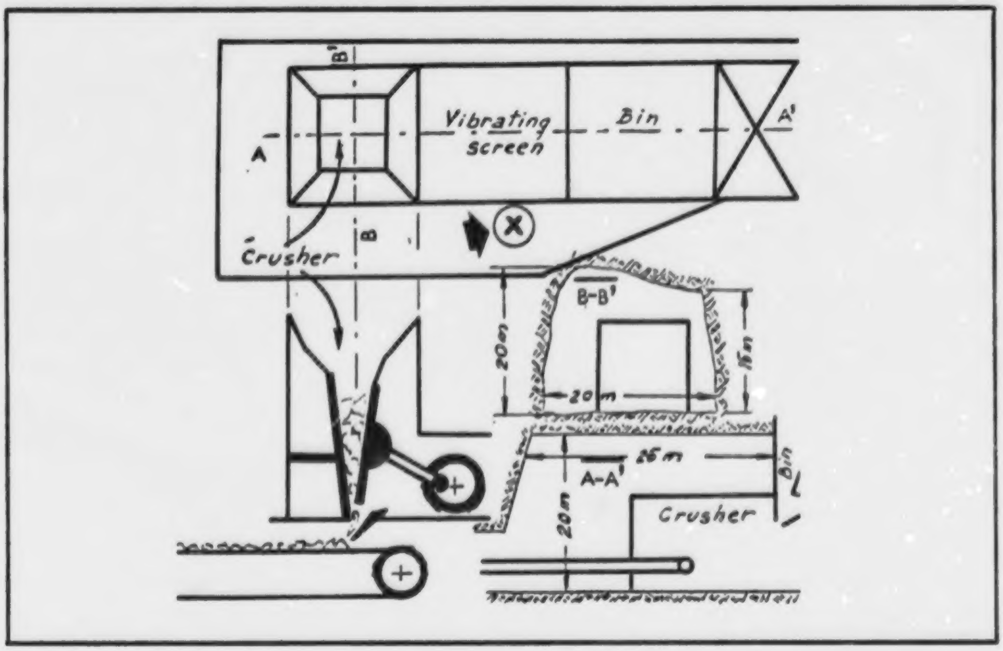
Number of personnel exposed: ______

Wearing ear protection? ☒ yes ☐ no

SIGNED: Miron Savich

RECOMMENDATION: ....

ELLIOT LAKE LABORATORY, MINES BRANCH, E. M. R.



Sketch showing microphone locations, orientation of the subject, distance from subject to microphone, and height of microphone above reflecting plane (direction of exhaust and size of load cell where applicable). Show measuring location with an X.

SUBJECT: JAW CRUSHER

Model: ________ Manufacturer: ________ Serial: ________
Rated Speed and Capacity: ________
Description: ________

TECHNICAL DATA:

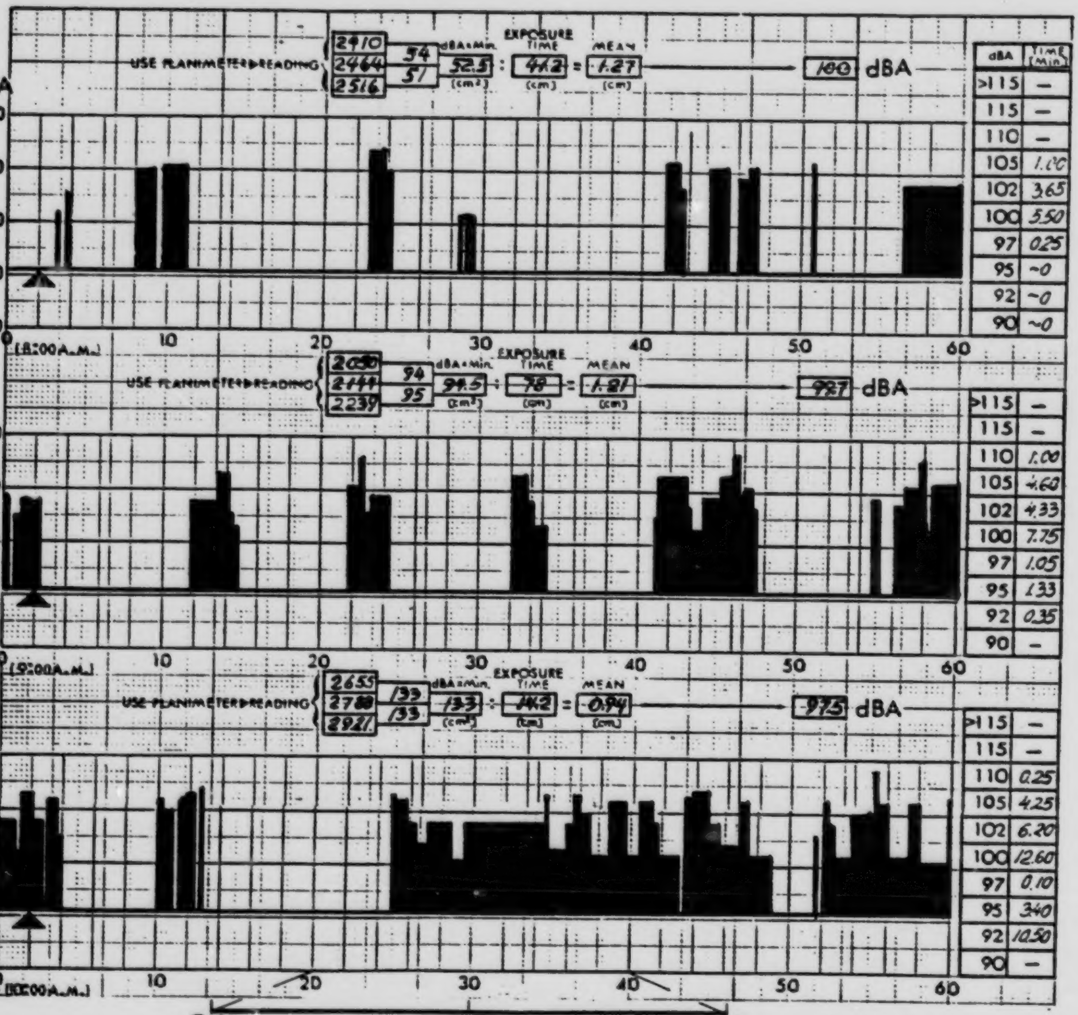
Steel type: ________
Length: ________ metres
Bit Type: ________
Muffler Type: ________
Air Pressure Supplied: ____ bars

Water Pressure Supplied: ____ bars
Airflow: ________ m^3/min
Blow Rate: ________ blow/min
Penetration: ________ m/min
Rock Type: QUARTZ CONGLOMERATE

NOTES: MEASUREMENTS TAKEN AT CRUSHER OPERATOR CONTROL PANEL (EAR LEVEL). MOST OF ORE FROM ORE PASS.

MINES LTD.
21/08/73

Crusher Operator
Histogram (~3000 tons/8 hours)



dBA	TIME (Min)
>115	—
115	—
110	—
105	1.00
102	3.65
100	5.50
97	0.25
95	~0
92	~0
90	~0

dBA	TIME (Min)
>115	—
115	—
110	1.00
105	4.60
102	4.33
100	7.75
97	1.05
95	1.33
92	0.35
90	—

dBA	TIME (Min)
>115	—
115	—
110	0.25
105	4.25
102	6.20
100	12.60
97	0.10
95	3.40
92	10.50
90	—

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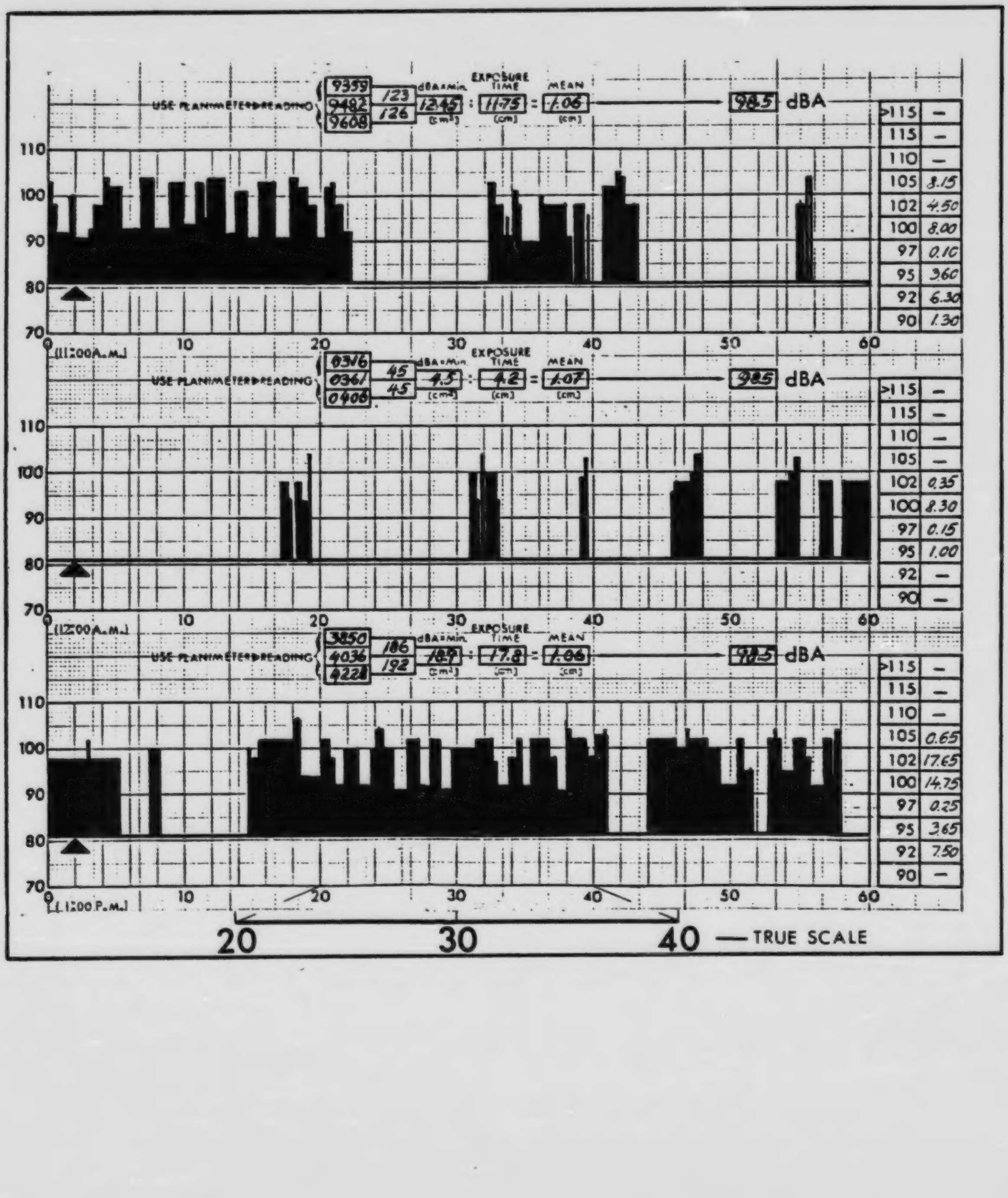
USE PLANIMETER READING
9359
9482
9608
123
126
dBA×min
12.45
(cm²)
EXPOSURE TIME
11.75
(cm)
MEAN
1.06
(cm)
98.5 dBA
>115 –
115 –
110 –
105 8.15
102 4.50
100 8.00
97 0.10
95 3.60
92 6.30
90 1.30
110
100
90
80
70
0
10
20
30
40
50
60
(11:00 A.M.)
USE PLANIMETER READING
0316
0361
0406
45
45
dBA×Min
4.5
(cm²)
EXPOSURE TIME
4.2
(cm)
MEAN
1.07
(cm)
98.5 dBA
>115 –
115 –
110 –
105 –
102 0.35
100 8.30
97 0.15
95 1.00
92 –
90 –
(12:00 A.M.)
USE PLANIMETER READING
3850
4036
4228
186
192
dBA×min
18.9
(cm²)
EXPOSURE TIME
17.8
(cm)
MEAN
1.06
(cm)
98.5 dBA
>115 –
115 –
110 –
105 0.65
102 17.65
100 14.75
97 0.25
95 3.65
92 7.50
90 –
(1:00 P.M.)
20
30
40
— TRUE SCALE

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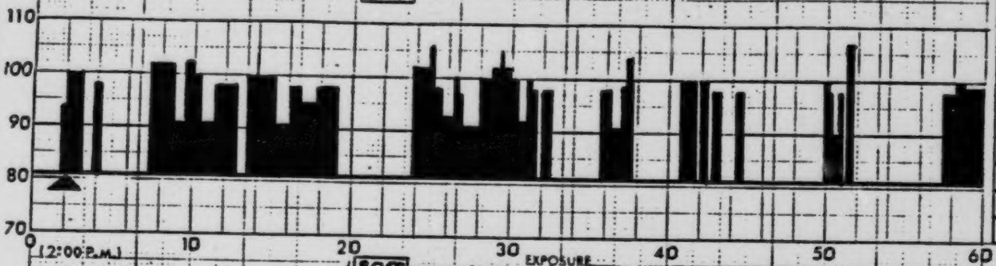
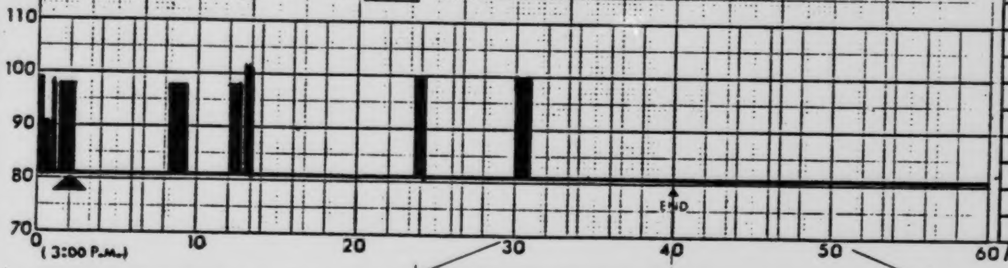
USE PLANIMETER READING 7593 / 7707 / 7817 — 114 / 110 — dBA × Min 11.2 (cm²) : EXPOSURE TIME 11.05 (cm) = MEAN 1.01 (cm) ——→ 98 dBA



>115	—
115	—
110	0.30
105	0.45
102	3.60
100	16.80
97	—
95	2.33
92	5.15
90	—

USE PLANIMETER READING 8059 / 8077 / 8096 — 18 / 19 — dBA × Min 1.85 (cm²) : EXPOSURE TIME 1.85 (cm) = MEAN 1.0 (cm) ——→ 98 dBA



>115	—
115	—
110	—
105	—
102	0.05
100	4.15
97	—
95	—
92	0.10
90	—

NOTE: ▲ = BACKGROUND NOISE 30 40 50 – TRUE SCALE

TIME / dBA	90	92	95	97	100	102	105	110	115	>115		TOTAL TIME	K dBA × Min	E EXPOSURE TIME	K/E
										120	125				
8:00-9:00AM	—	—	—	0.25	3.50	3.65	1.00	—	—	—	—		52.5	41.2	
9:00-10:00AM	—	0.35	1.33	1.05	7.75	4.33	4.60	1.00	—	—	—		94.5	78	
10:00-11:00AM	—	10.50	3.40	0.10	12.60	6.20	4.25	0.25	—	—	—		13.3	14.2	
11:00-12:00AM	1.30	6.30	3.60	0.10	8.00	4.50	8.15	—	—	—	—		12.45	11.75	
12:00-1:00PM	—	—	1.00	0.15	8.30	0.35	—	—	—	—	—		4.5	4.2	
1:00-2:00PM	—	7.50	3.65	0.25	14.75	17.65	0.65	—	—	—	—		18.9	17.8	
2:00-3:00PM	—	5.15	2.33	—	16.80	3.60	0.45	0.30	—	—	—		11.2	11.05	
3:00-4:00PM	—	0.10	—	—	4.15	0.05	—	—	—	—	—		1.85	1.85	
C TOTAL DURATION (MIN)	1.30	29.90	15.31	1.90	77.35	40.35	19.10	1.55	—	—	—	187.84	= 209.20	180	1.16
T PERMISSIBLE MIN PER DAY	480	360	240	180	120	90	60	30	15	NONE		Σ C/T			
C/T	~0	0.083	0.064	0.011	0.649	0.448	0.32	0.05	—	—	—	1.625 EXPOSURE INDEX			

ARITHMETIC MEAN 99 dBA

RECOMMENDATION: ______________________________

SIGNED: ______

APPENDIX C

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

Plant-Noise Survey Form

DATE: 22-08-73
METER #: 2205 B.4K

LOCATION: MINES LTD.
UNDERGROUND CRUSHER

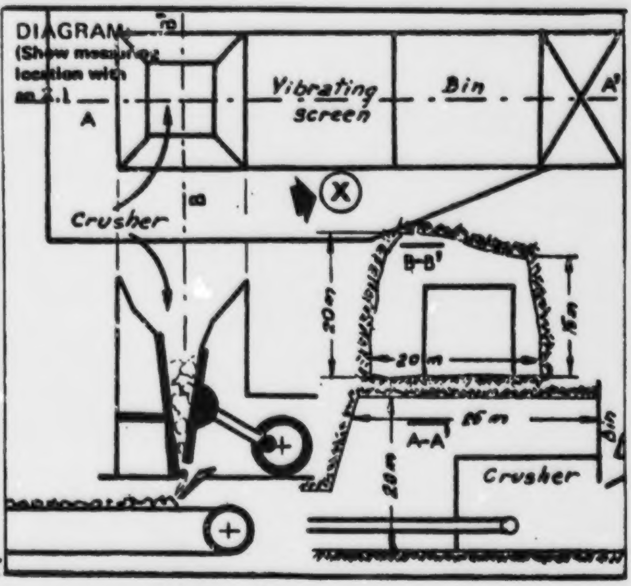
NUMBER OF PERSONNEL EXPOSED:

WEARING EAR PROTECTION? ☒ yes ☐ no

OPERATOR: M. SAVICH

Equipment JAW CRUSHER.
Manufacture
Steel type
Length (m.)
Bit type
Muffler type
Air kPa
Water kPa
Airflow m³./min.
Blow rate (blow/min.)
Penetation m./min.
Rock type. QUARTZ CONGLOMERATE

DIAGRAM: (Show measuring location with an X.)



NOTES: MEASUREMENTS TAKEN AT CRUSHER OPERATOR CONTROL PANEL (EAR LEVEL). MOST OF ORE FROM ORE PASS

MAXIMUM LEVELS AS MEASURED ON THE "As" SCALE OF THE SOUND-LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.

dBA MAX LEVEL		C TOTAL DURATION IN HOURS PER DAY	T PERMISSIBLE HOURS PER DAY	C/T
OVER 115			NONE	
115			¼	
110	0.0202 + 0.0035 + 0.0005 + 0.0038	.0280	½	.056
105	0.1094 + 0.0494 + 0.0279	.1867	1	.187
102	0.2935 + 0.2187	.5120	1½	.341
100	0.6260 + 0.3807	1.0067	2	.503
97	0.0941 + 0.0919	.1860	3	.062
95	0.1041 + 0.0188 + 0.0435	.1664	4	.042
92	0.2385 + 0.2500	.4885	6	.081
90	0.0716	.0716	8	.009
	Σ	2.6459		

IMPACT CHECK MUST BE UNDER 140 dB PEAK SOUND-PRESSURE LEVEL AS MEASURED WITH AN IMPACT NOISE ANALYZER, OR BE UNDER 125 dB AS MEASURED WITH A SOUND-LEVEL METER ON C WEIGHTING, FAST RESPONSE, 140 dB FULL SCALE RANGE.

MAX- dB(C)

TOTAL 1.281

To comply with regulations, total cannot be more than 1.

RECOMMENDATIONS:

SIGNED: Miroy Savich

ELLIOT LAKE LABORATORY, MINES BRANCH, E.M.R.

OSHA
Noise Survey Form

B & K 166 Environmental Noise Classifier

Test must coincide with full work shift.

Date: 22/08/1973

Time from 8:00 A.M. to 4:00 P.M.

Location: Mines Ltd.

Made by: Miran Savich

Instrument No. ____

Base Line set at 90 dB (normally 90) and Weighting Selector set at 90.

Total test time 485.4 minutes

EQUIPMENT TESTED (SEE OTHER SIDE FOR DETAILS):

JAW CRUSHER

SHEET: 1

Exposure in Minutes												
90 to 92 dBA	92 to 95 dBA	95 to 97 dBA	97 to 100 dBA	100 to 102 dBA	102 to 105 dBA	105 to 107 dBA	107 to 110 dBA	110 to 112 dBA	112 to 115 dBA	Over 115 dBA to 120	Over 115 dBA to 125	Exposure Value (%)
480 420 360 300 240 180 120 60	320 280 240 200 160 120 80 40	240 210 180 150 120 90 60 30	160 140 120 100 80 60 40 20	120 110 100 90 80 70 60 50 40 30 20 10	80 70 60 50 40 30 20 10	60 50 40 30 20 10	40 35 30 25 20 15 10 5	30 25 20 15 10 5	20 15 10 5	Not Permissible		130 120 110 100 90 80 70 60 50 40 30 20 10
17.1	4.0	18.3	41.3	43.4	18.4	1.9	0.7	0.1	–	–	–	
3.5	0.5	4.0	34.5	46.5	30.5	3.5	2.0	~0				

1. Enter time in minutes from counters on the 166. →
2. Enter Exposure Value (%) from right-hand column corresponding to minutes in table. →
3. Add Exposure Values 125 = % Permissible Exposure
4. Divide % Permissible Exposure by 100 to obtain OSHA Mixed Exposure Index 1.25

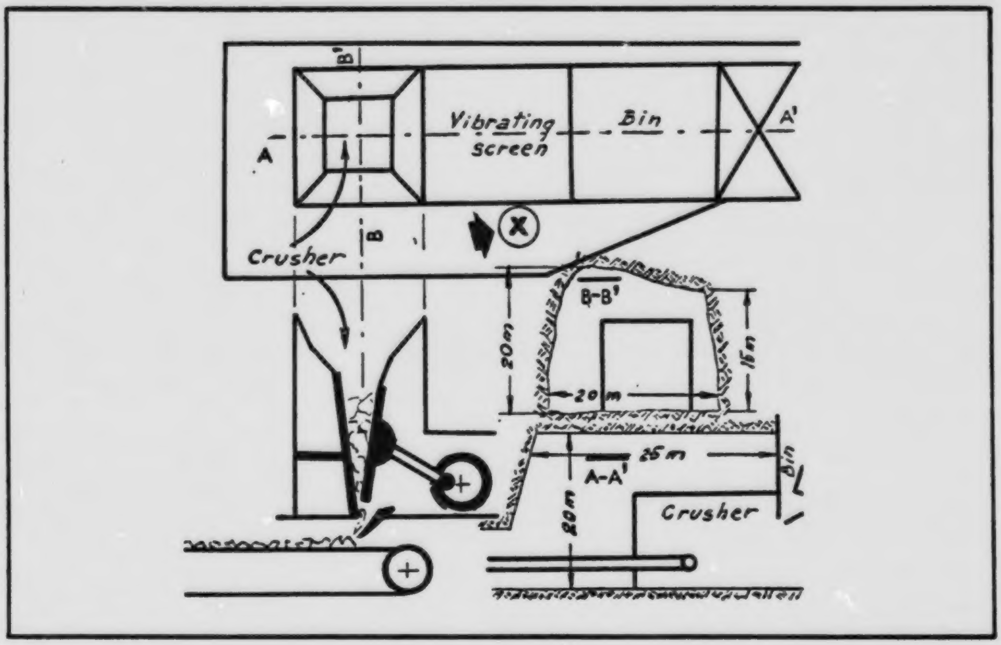
Number of personnel exposed: 1

Wearing ear protection? ☒ yes ☐ no

SIGNED: Miran Savich

RECOMMENDATION: ....

ELLIOT LAKE LABORATORY, MINES BRANCH, E. M. R.



Sketch showing microphone locations, orientation of the subject, distance from subject to microphone, and height of microphone above reflecting plane (direction of exhaust and size of load cell where applicable). Show measuring location with an **X**.

SUBJECT: JAW CRUSHER

Model: ________ Manufacturer: ________ Serial: ________
Rated Speed and Capacity: ________
Description: ________

TECHNICAL DATA:

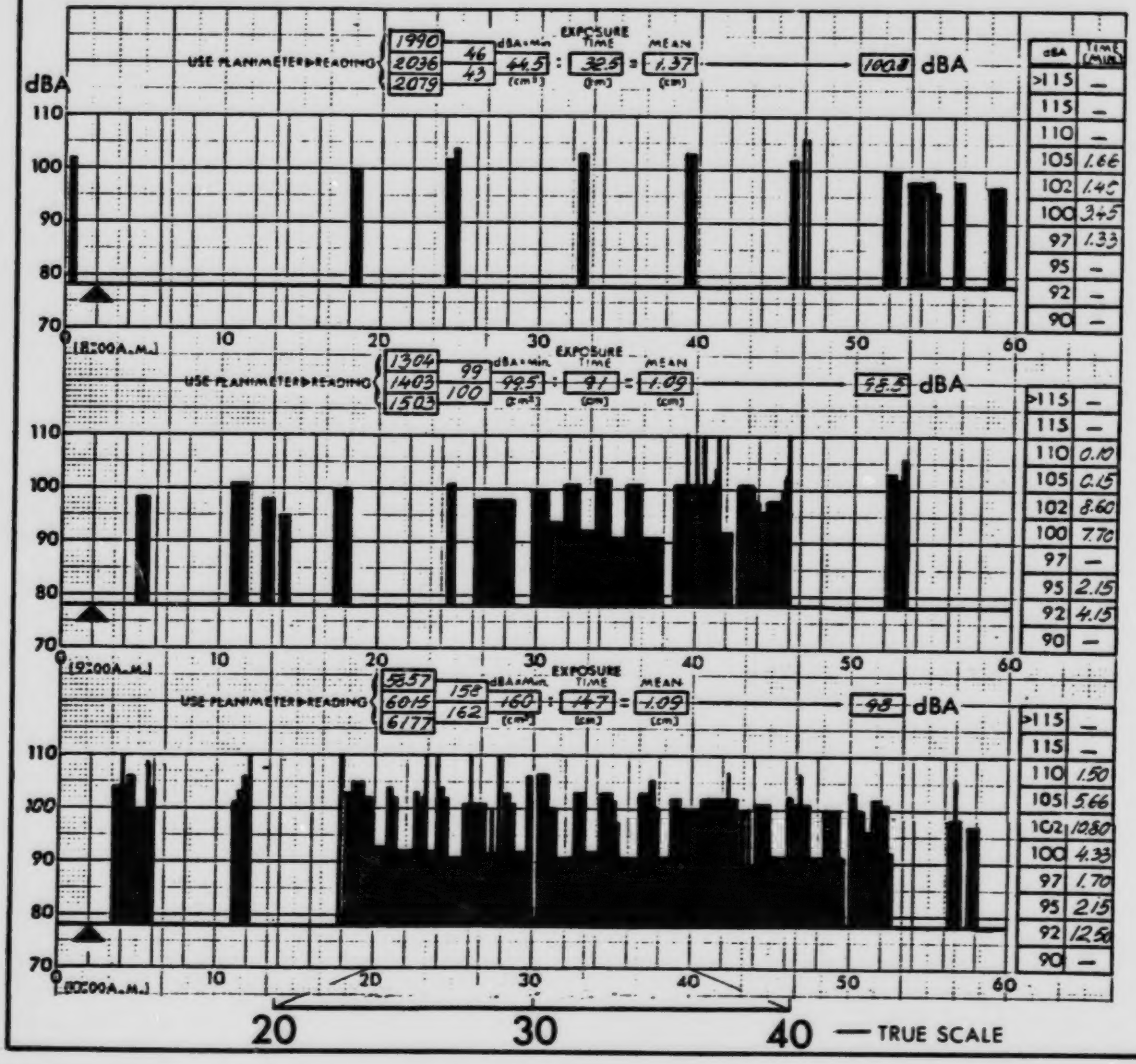
Steel type: ________
Length: ________ metres
Bit Type: ________
Muffler Type: ________
Air Pressure Supplied: ____ bars

Water Pressure Supplied: ____ bars
Airflow: ________ m^3/min
Blow Rate: ________ blow/min
Penetration: ________ m/min
Rock Type: QUARTZ CONGLOMERATE

NOTES: MEASUREMENTS TAKEN AT CRUSHER OPERATOR CONTROL PANEL (EAR LEVEL).

MINES LTD.
22/08/73

Crusher Operator
Histogram (- 3000 tons/8 hours)

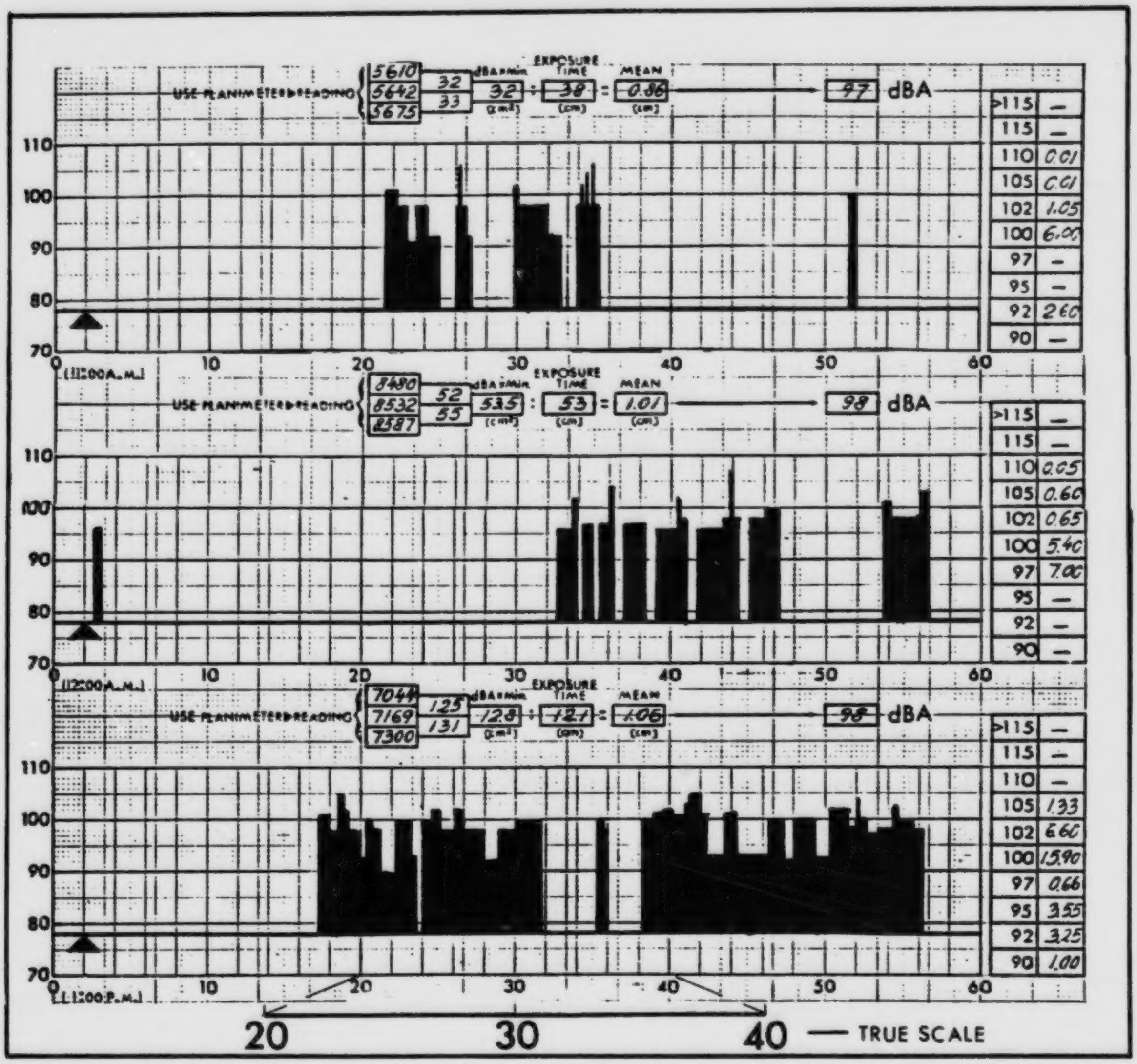


dBA	TIME (MIN)
>115	—
115	—
110	—
105	1.66
102	1.45
100	3.45
97	1.33
95	—
92	—
90	—

>115	—
115	—
110	0.10
105	0.15
102	8.60
100	7.70
97	—
95	2.15
92	4.15
90	—

>115	—
115	—
110	1.50
105	5.66
102	10.80
100	4.33
97	1.70
95	2.15
92	12.50
90	—

80/503



USE PLANIMETER READING 5610 / 5642 / 5675 — 32 / 33 — dBA×min 32 (cm²) : EXPOSURE TIME 38 (cm) = MEAN 0.86 (cm) → 97 dBA

>115	—
115	—
110	0.01
105	0.01
102	1.05
100	6.00
97	—
95	—
92	2.60
90	—

USE PLANIMETER READING 8480 / 8532 / 8587 — 52 / 55 — dBA×min 53.5 (cm²) : EXPOSURE TIME 53 (cm) = MEAN 1.01 (cm) → 98 dBA

>115	—
115	—
110	0.05
105	0.60
102	0.65
100	5.40
97	7.00
95	—
92	—
90	—

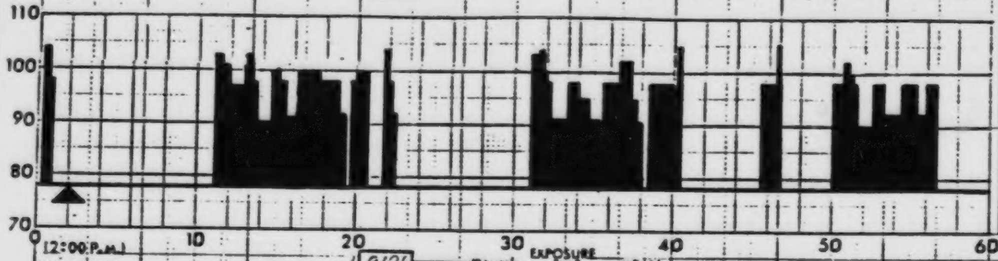
USE PLANIMETER READING 7044 / 7169 / 7300 — 125 / 131 — dBA×min 128 (cm²) : EXPOSURE TIME 121 (cm) = MEAN 1.06 (cm) → 98 dBA

>115	—
115	—
110	—
105	1.33
102	6.60
100	15.90
97	0.66
95	3.55
92	3.25
90	1.00

801503

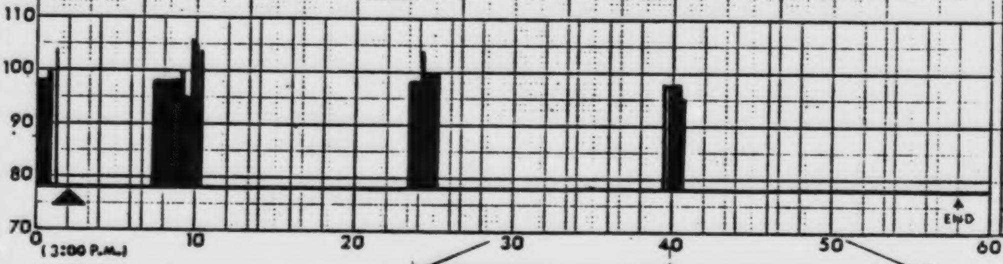
USE PLANIMETER READING: 7240 / 7327 / 7415 → 87 / 88 → dBA x Min. 87.5 (cm²) : EXPOSURE TIME 94 (cm) = MEAN 0.93 (cm) ——→ 97.5 dBA

>115	—
115	—
110	0.01
105	2.20
102	1.33
100	12.10
97	0.75
95	1.20
92	5.40
90	2.00



USE PLANIMETER READING: 9124 / 9146 / 9172 → 22 / 26 → dBA x Min. 24 (cm²) : EXPOSURE TIME 24 (cm) = MEAN 1.0 (cm) ——→ 98 dBA

>115	—
115	—
110	—
105	0.30
102	—
100	1.33
97	4.00
95	1.00
92	—
90	—



NOTE: ▲ = BACKGROUND NOISE 30 40 50 — TRUE SCALE

TIME \ dBA	90	92	95	97	100	102	105	110	115	>115 120	>115 125
8:00–9:00 AM	—	—	—	1.33	3.45	1.40	1.66	—	—	—	—
9:00–10:00 AM	—	4.15	2.15	—	7.70	8.60	0.15	0.10	—	—	—
10:00–11:00 AM	—	12.50	2.15	1.70	4.33	10.80	5.66	1.50	—	—	—
11:00–12:00 AM	—	2.60	—	—	6.00	1.05	0.01	0.01	—	—	—
12:00–1:00 PM	—	—	—	7.00	5.40	0.65	0.60	0.05	—	—	—
1:00–2:00 PM	1.0	3.25	3.55	0.66	15.90	6.60	7.33	—	—	—	—
2:00–3:00 PM	2.0	5.40	1.20	0.75	12.10	1.33	2.20	0.01	—	—	—
3:00–4:00 PM	—	—	1.00	4.00	1.33	—	0.30	—	—	—	—
C TOTAL DURATION (MIN)	3.0	27.9	10.05	15.44	56.21	30.43	11.91	1.67	—	—	—
T PERMISSIBLE MIN PER DAY	480	360	240	180	120	90	60	30	15	NONE	
C/T	~0	0.078	0.042	0.086	0.468	0.338	0.198	0.056	—	—	—

TOTAL TIME: 156.61

Σ C/T: 1.266 EXPOSURE INDEX

	K dBA x Min	θ EXPOSURE TIME	K/θ
	44.5	32.5	
	99.5	94	
	160	147	
	32	38	
	53.5	53	
	12.8	12.1	
	87.5	94	
	24	24	
Σ	513.8	491.6	1.05

ARITHMETIC MEAN 98 dBA

RECOMMENDATION: ______________________

SIGNED: ______________________

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Vol. 1 Report 3

74-23 M. Savich

A new graphical method for testing noise exposure

1974

Casque de surveillance du bruit

par

Miron Savich*

RÉSUMÉ

Un casque de surveillance du bruit combinant un casque protecteur et un dosimètre de bruit est décrit. Le dosimètre donne une indication de l'exposition au bruit exprimée en pourcentage qui satisfait les normes OSHA. Le dosimètre pèse environ 240 g (8 oz) et ne devrait pas gêner le mineur. Le nouvel instrument calcule automatiquement les niveaux de bruit pendant un quart de travail complet; la participation active du mineur n'est donc pas nécessaire. L'adoption de ce type de système de mesure devrait permettre de recueillir des données complètes sur l'exposition au bruit des travailleurs dans divers domaines, avec une interférence minimale. Les méthodes de manipulation sont très simples et la manipulation peut être confiée à une personne non qualifiée.

Bruit : Exposition : Dosimètre : Casque protecteur

* Chercheur, Laboratoire d'Elliot Lake, Laboratoires de recherche minière, Centre canadien de la technologie des minéraux et de l'énergie, ministère de l'Énergie, des Mines et des Ressources, Elliot Lake (Ontario).

Noise Monitor Hat

by

Miron Savich*

- - - - - - - - - -

ABSTRACT

A design of a Noise Monitor Hat is presented which combines a protective headwear with a noise dosimeter. The dosimeter gives a readout in percentage noise exposure which meets OSHA criteria. The weight of a dosimeter is about 240 g (8 oz) which should not hinder the activities of the miner. The instrument automatically integrates the noise levels over a full-shift period and hence the active participation of the miner is not required. Adoption of this type of measuring system would permit collection of comprehensive records of noise exposure for workers in various occupations with minimal interference. Guideline handling procedures are very simple and can be performed by an unqualified person.

Noise: Exposure: Dosimeter: Protective Headwear

*Research Scientist, Elliot Lake Laboratory, Mines Branch, Mining Research Centre, Department of Energy, Mines and Resources, Elliot Lake, Ontario.

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2. Design---1
2.1 Technical Description--------------------------------2
2.2 Application for Other Noise Dosimeters---------------4
2.3 Guidline Handling Procedures-------------------------6
3. Conclusion---6
4. References---8
Appendix: Design For Noise Monitor Hat

TABLE

1. Noise Exposure Meters with and without Readout Unit---5

1. INTRODUCTION

As a result of the promulgation of occupational noise exposure regulations by the OSHA (Occupational Safety and Health Standards, Sec. 1910.95 as printed in the Federal Register, Vol. 36, No. 105, Part II), there are a number of commercial noise exposure meters on the market today that provide a measure of noise integrated over a time interval.

Tests have shown that there exists a wide variation in performance among various noise exposure meters (1 to 12). It is evident that a performance standard for these instruments is an absolute necessity. American National Standards Institute Working Group S1-W45 is working on such a standard which should provide the following guidance:

a) microphone placement on the body,
b) calibration, and
c) guideline handling procedures

which the performance standard may not cover.

The purpose of this report is to contribute to the solution of this problem: to measure the noise exposure by a simple method which will meet OSHA* criteria requirements.

2. DESIGN

The basic idea of this design is to place the microphone as near to the ear as possible and in such a way that it does not disturb the worker. The handling procedures are also simplified. In this design a protective headwear, class "C", and an E.J. du Pont de Nemours and Co. Audio Dosimeter (13 and 14) are used.

---

*The Occupational Safety and Health Act.

Protective headwear - hats and caps - under class "C" are intended for protection against impact and flying particles. This class offers no dielectric protection. The hat is used in mining, construction and in almost all industry. For protective headwear class "C", the weight of any hat or cap shall not exceed 529 g (15 oz) complete with suspension but exclusive of any winter lining, chin strap, nape strap, lamp bracket or other attachment. For this design the model M-S-A, TOPGARD, protective hat or cap with adjustable head sizes 6 3/8 to 8, weight ~ 454 g, is used. For the purpose of designing a Noise Monitor Hat the dimensions, weight and specifications of E.J. du Pont Audio Dosimeter were used (14).

2.1 Technical Description

The layout and components of the Noise Monitor Hat are given in the Appendix. The standard du Pont Audio Dosimeter was separated into two parts to give balance to the hat. A microphone and a battery are located in the right housing and the electronic parts in the left housing. The weight of the two housings is almost the same - about 120 g (Appendix, 3 and 4). Each housing is fixed by four screws. Between the housing and the hat a rubber layer serves to better seal the the instrument. Both parts are connected with cables and fixed inside the hat (Appendix, No. 11 and 12).

In the right housing the 1/2" microphone with preamplifier or 1" microphone is built-in, in such a manner that it can easily be taken out, with a screw for adjusting the microphone, for calibration or checking of the instrument (Appendix, No. 8 and 24). If we build-in a 1" microphone, the right housing will be larger because of the size of the microphone. The microphone is protected by a grid and windscreen. The windscreen is fixed by epoxy on the sliding microphone cover (Appendix, No. 21 and 22) and has two functions: protection from air drafts and from dust. In the housing there is enough room to allow adjustment of the microphone. Every head movement is followed by the movement of the microphone and the same angle value related to the ear. In this way an excellent result will be obtained.

In the left housing the built-in electronic system is hermetically sealed. The information which is stored in a small memory cell is completely protected from inadvertent loss and is not available to the person wearing the Noise Monitor Hat. Information stored in the cell is permanently recorded until the results are retrieved in a separate readout device (Appendix, No. 16). By depressing a check button in the Dosimeter (Appendix, No. 18) or a flat-head Allen screw with off-on pin (Appendix, No. 19 and 20) in the Noise Monitor Hat at the conclusion of the measurement period, a light-emitting diode (Appendix, No. 17) indicates whether or not the employee was exposed to any continuous noise over 115 dBA during the work period. In the left housing a small window serves for the observation of the light-emitting diode (Appendix, No. 4).

All systems in the Noise Monitor Hat are very rugged. The housings are resistant to impact, abrasion and chemical attack. The major components are encapsulated in plastic. The Noise Monitor Hat will withstand extremes of humidity and temperature.

2.2 Application for Other Noise Dosimeters

In the same way, the Bendix 1150 Noise Exposure Monitor (15) General Radio 1944-I Noise Exposure Monitor (16) and computer engineering Noise Dosimeter Type 122 (17) can be adapted (Table 1).

In the Bendix 1150 Noise Exposure Monitor, the microphone must be changed from a 1" (Shure 99 A 401) to a 1/2" condenser microphone with preamplifier. The condenser microphone's operating characteristics of high stability, flat linear response and high sensitivity combine with its minimal effect on the sound field in which it is placed.

The cable length which can be used with the microphone depends upon the output impedance of the microphone and the cable impedance. When the cable impedance is much less than the microphone impedance, part of the signal is lost. The Shure microphone has an output capacity of about 500 pF (18). By way of example for comparison, the B & K microphone of 1/2" diameter has an output capacity of only 18 pF. It is very difficult and totally impractical to find a cable which, together

TABLE 1

Noise Exposure Meters with and without Readout Unit

	Company	Instrument	Microphone	Weight
1.	Bendix National Environmental Instruments	1150 Noise Exposure Monitor 1100 Readout Unit	Shure 99 A 401 Ceramic 1"	227 g
2.	E.J. du Pont de Nemours and Co.	Audio Dosimeter Model D-100 or D-285 Audio Dosimeter Readout R-150 Audio Dosimeter Calibrator Model C-114	Shure 99 A 401 Ceramic 1"	241 g
3.	General Radio	GR 1944-I Noise Exposure Monitor, GR 1944-I Noise Exposure Indicator	GR Ceramic 1/2"	210 g
4.	Computer Engineering Ltd.	Noise Dosimeter Type 122 Acoustic Calibrator Type 129	Shure 99 A 401 Ceramic 1"	230 g

with the switches, has a capacity of only a few tenths of a picofarad and is long enough to be used. For this reason, with the condenser microphone a preamplifier is used which serves as an impedance transformer. It is clear that some changes must be made in the input electronic circuit of the dosimeter.

In the left housing the electronic component must be built-in so that they can be simply taken off and plugged into the readout unit. This can be solved by a short cable too, but in this case the readout unit has to undergo changes.

The General Radio 1944-I Noise Exposure Monitor has a built-in microphone of 1/2", but the reconstruction of the readout unit is as for the Bendix.

The Computer Engineering Ltd. Noise Dosimeter integrates to the equal energy damage risk criteria as set out in the international standard 1SO R 1999.

2.3 Guideline Handling Procedures

It is envisaged that several Noise Monitor Hats would be available at a mine. On a rotational basis these hats would be issued to the workers for a full shift. In this way the testing procedure is performed continuously and an unqualified person could administer it.

To satisfy the workers' curiousity it is proposed that a hat with plexiglass housings and simulated built-in elements be exhibited in the staging area.

The test result is noted in the noise exposure record of the worker. The final result of personal noise monitoring is a function of the statistical sampling of the work environment.

3. CONCLUSION

The design allows for new proposals for further development of the Noise Monitor Hat. The proposed system can be applied to the protective headwear class "C" and does not conflict with CSA standards (13).

It is proposed to make one or more prototype models and subject them to rigorous testing in the mine environment to ensure reliability of the instrument and measurements.

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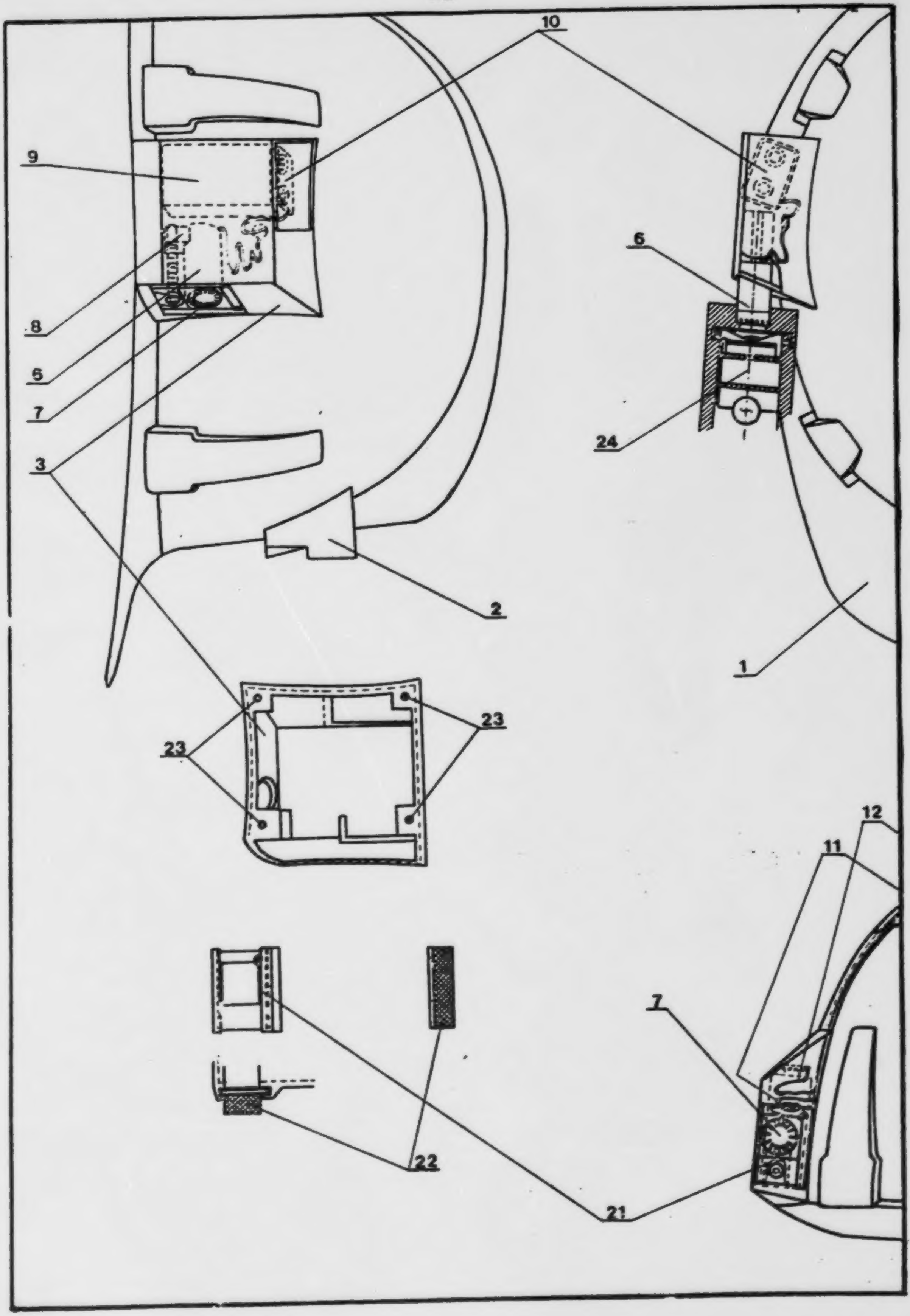
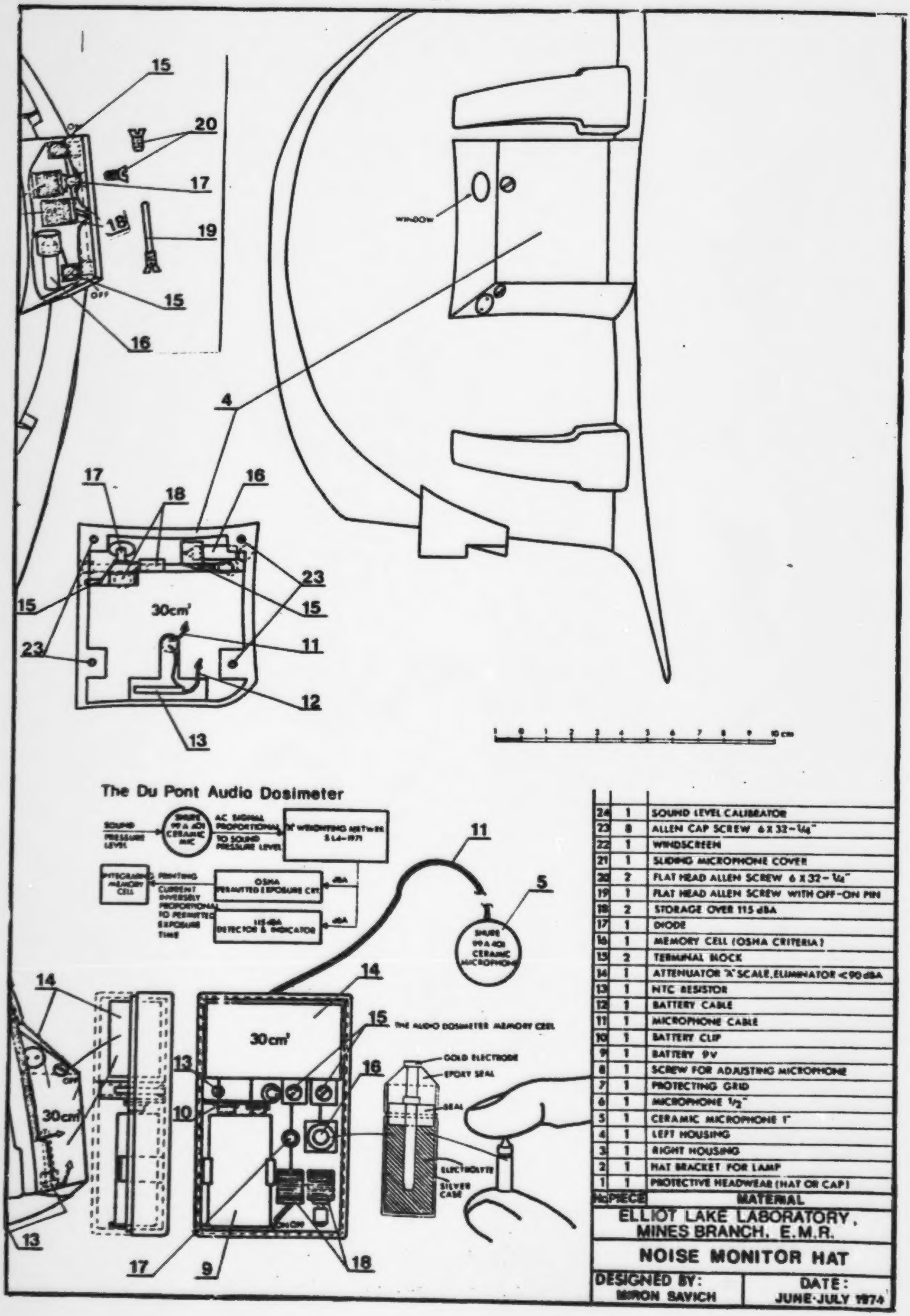
APPENDIX

DESIGN FOR NOISE MONITOR HAT




15
20
17
18
19
15
OFF
16
WINDOW
4
17
18
16
23
15
15
30cm²
11
23
12
13
0 1 2 3 4 5 6 7 8 9 10 cm
The Du Pont Audio Dosimeter
SOUND PRESSURE LEVEL
SHURE 99 A 401 CERAMIC MIC
AC SIGNAL PROPORTIONAL TO SOUND PRESSURE LEVEL
"A" WEIGHTING NETWORK S1.4-1971
INTEGRATING MEMORY CELL
PRINTING CURRENT INVERSELY PROPORTIONAL TO PERMITTED EXPOSURE TIME
OSHA PERMITTED EXPOSURE CKT
dBA
115 dBA DETECTOR & INDICATOR
dBA
11
5
SHURE 99 A 401 CERAMIC MICROPHONE
14
14
OFF
30cm²
13
30cm²
15
THE AUDIO DOSIMETER MEMORY CELL
13
16
10
GOLD ELECTRODE
EPOXY SEAL
SEAL
ELECTROLYTE
SILVER CASE
ON OFF
13
17
9
18

No	PIECE	MATERIAL
24	1	SOUND LEVEL CALIBRATOR
23	8	ALLEN CAP SCREW 6 X 32 - 1/4"
22	1	WINDSCREEN
21	1	SLIDING MICROPHONE COVER
20	2	FLAT HEAD ALLEN SCREW 6 X 32 - 1/4"
19	1	FLAT HEAD ALLEN SCREW WITH OFF-ON PIN
18	2	STORAGE OVER 115 dBA
17	1	DIODE
16	1	MEMORY CELL (OSHA CRITERIA)
15	2	TERMINAL BLOCK
14	1	ATTENUATOR "A" SCALE, ELIMINATOR < 90 dBA
13	1	NTC RESISTOR
12	1	BATTERY CABLE
11	1	MICROPHONE CABLE
10	1	BATTERY CLIP
9	1	BATTERY 9V
8	1	SCREW FOR ADJUSTING MICROPHONE
7	1	PROTECTING GRID
6	1	MICROPHONE 1/2"
5	1	CERAMIC MICROPHONE 1"
4	1	LEFT HOUSING
3	1	RIGHT HOUSING
2	1	HAT BRACKET FOR LAMP
1	1	PROTECTIVE HEADWEAR (HAT OR CAP)

ELLIOT LAKE LABORATORY,
MINES BRANCH, E.M.R.

NOISE MONITOR HAT

DESIGNED BY:	DATE:
MIRON SAVICH	JUNE-JULY 1974

VOL.1 Report 4

74-88 M. Savich

Noise monitor hat

1974

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Analyse de la performance de dosimètres de bruit et d'appareils de surveillance de l'exposition au bruit

par

M. Savich*

RÉSUMÉ

Une analyse détaillée de dosimètres de bruit et d'appareils de surveillance de l'exposition au bruit a été menée à partir de données fournies par les fabricants et de résultats obtenus dans nos essais sur le terrain et au laboratoire. Le but de cette recherche était d'étudier la possibilité d'utiliser ces appareils dans les mines et usines canadiennes. Ces instruments étant encore au stade de la mise au point, il convient d'établir des normes relatives aux aspects suivants :

- emplacement du microphone sur le corps
- vérifications minimales recommandées avant l'usage
- méthodes de manipulation

Les problèmes de l'application des dosimètres de bruit sont encore à l'étude.

Bruit : Exposition : Dosimètre : Appareil de surveillance

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Performance Analysis on Noise Dosimeters and Noise Exposure Monitors

by

M. Savich*

ABSTRACT

A detailed analysis on noise dosimeters and noise exposure monitors was conducted on the basis of data compiled from manufacturers literature, and our laboratory and field tests. The goal of this research was to investigate the possibility of utilization of these devices in Canadian mines and mills. As these instruments are still in the development stage, it is necessary to provide standards such as:

-microphone placement on the body,

-minimum recommended checks prior to usage, and

-handling procedure guidelines.

The problems of applying noise dosimeters are still under study.

Noise: Exposure: Dosimeter: Monitor

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1. INTRODUCTION

The Elliot Lake Laboratory is interested in the possibility of utilizing personal noise dosimeters and monitors to estimate the noise exposure in Canadian mines and mills. In a study in our laboratory we are establishing the following criteria for evaluating the performance of these instruments:

1. the data compiled from the manufacturers,
2. the data assembled from literature,
3. the data obtained in our laboratory and performed in a mining noise environment.

The noise dosimeters and monitors are similar in design except the data storage circuit.

2. INSTRUMENTS AND THEIR USE

Noise is not a new hazard, but the measurement and evaluation of daily noise exposure in Canadian mines has just begun. Standards limiting human exposure to maximum permissible levels of noise have been based on damage risk criteria. Instruments are required to determine the noise level and noise exposure. The manufacturers of both instruments claim compliance with ANSI S1.4-1971, Type S2A*, when used for A-weighted sound level, slow response.

---

* ANSI S1.4-1971, Type S2A, American National Standards Institute specification for Sound Level Meter.

A portable personal audio dosimeter has been designed and developed to determine acceptable noise levels for men working in industry. The basic relationship between the dBA scale and the percentage scale of the dosimeter is that a change of 5 dBA doubles the percentage reading. The OSHA criterion operates on the basis that a 5 dBA increase in sound level requires half the duration to give the same noise dose. The effects on percentage are even greater at the higher frequencies (Table 1).

The simplest method of obtaining an assessment of the risk of hearing damage under varying conditions is the use of a personal noise dosimeter which the worker wears wherever he goes. This instrument performs its measurements with absolutely no effort on the part of the employee. Of equal importance, its light weight and small size permit it to be worn without hindering the employee's work. This is not always true of the full-size dosimeter which often disturbs the miner at work.

The noise dosimeter design is based on a mathematical function (1):

$$L_{eq} = \frac{q}{\log_{10} 2} \log_{10} \left[\frac{1}{T} \int_{o}^{T} \left(\frac{p(t)}{p_o} \right)^{\frac{20 \log_{10} 2}{2}} dt \right]$$

(Equation 1)

where, L_{eq} is the equivalent continuous sound level,
q is a constant,
$p(t)$ is the varying sound level, and
p_o is the reference sound pressure, 2×10^{-5} Pa
T is the measurement duration in hours.

The value of q depends on the relationship between the sound intensity and its duration.

TABLE 1

The Effect of Instrument Tolerance Limits on Noise Exposure Readings

Sound Level Meter ANSI S1.4-1971, Type S2A		Dosimeter Reading when Expecting 100% Exposure Based on OSHA Criteria	
Frequency Hz	A-Weighting dB		
31.5	+3.5, -4.0	162.4,	57.4
63	+3.0, -3.0	151.6,	66.0
125	+2.5, -2.5	141.4,	70.7
250	+2.5, -2.5	141.4,	70.7
500	+2.0, -2.0	132.0,	75.8
1000	+2.0, -2.0	132.0,	75.8
2000	+3.0, -3.0	151.6,	66.0
4000	+5.5, -4.5	214.4,	53.6
8000	+6.5, -6.5	246.2,	40.6

There are two types of dosimeters (Figure 1). Both types use a ceramic microphone with an amplifier which supplies an A-weighting network. The output signal goes to an integrator circuit which produces a DC voltage which doubles for each increase of 5 dB in the noise level at the microphone input. In one type (A, Figure 1), the signal is fed to an electrochemical memory cell and causes plating on the electrodes. The amount of plating is then measured. In the second type (B, Figure 1), the signal from the integrator circuit is converted to pulses that are counted and later read out as an exposure index.

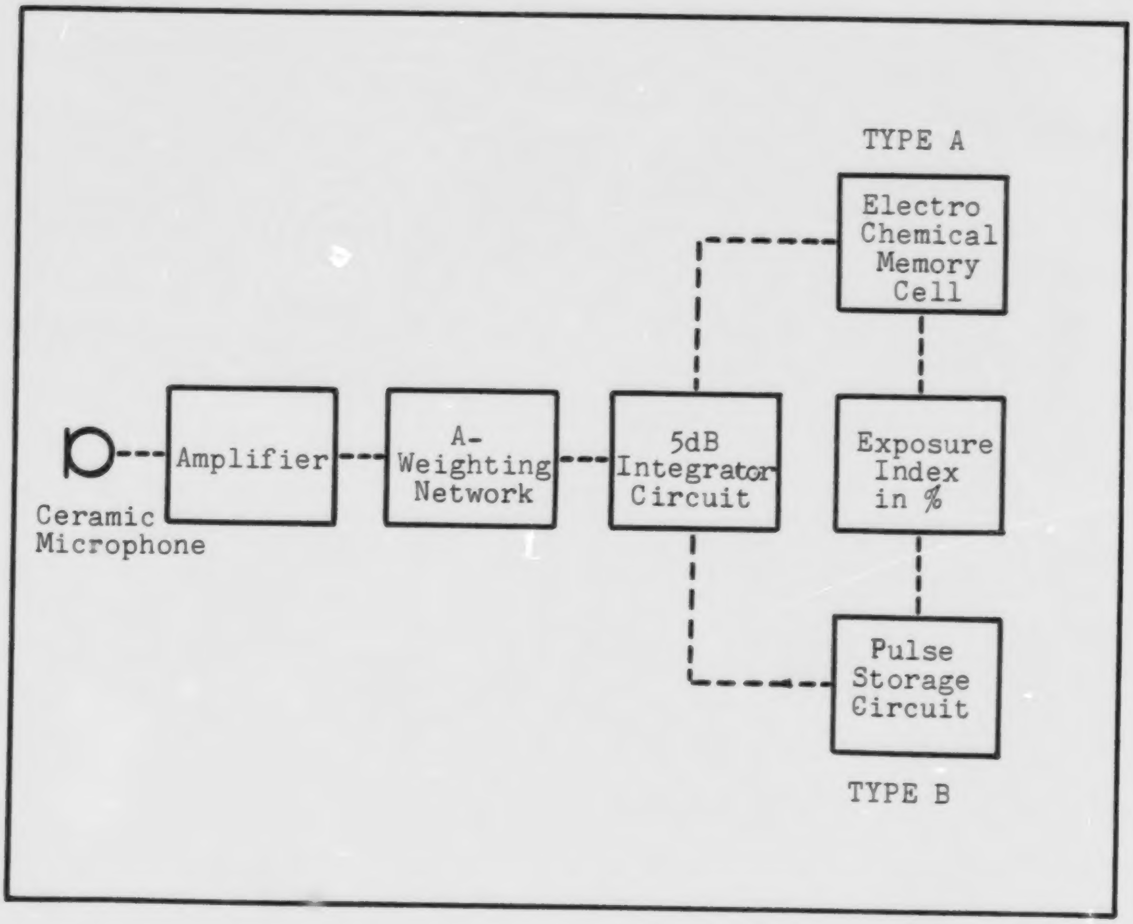

TYPE A
Electro Chemical Memory Cell
Amplifier
A-Weighting Network
5dB Integrator Circuit
Exposure Index in %
Ceramic Microphone
Pulse Storage Circuit
TYPE B

FIGURE 1: Two Types of Noise Dosimeters.

3. PERSONAL NOISE EXPOSURE DOSIMETERS ON THE MARKET

Several types of Noise Exposure Dosimeters are on the market (2 to 12). They measure the true accumulated noise exposure according to the Occupational Safety and Health Act (OSHA) or the International Standards Organization (ISO) Recommendation 1999 (R 1999) requirements (Table 2).

From this table we can see that no one instrument guarantees the measurement accuracy if the humidity is over 90%. In Canadian mines, in summer, the humidity is between 85 and 100%.

Most of the instruments are designed for the observation of the lower noise levels in industry, because they have a low storage capacity. In view of calibration there are two types of instruments: those which can be calibrated in the field, and those that must be calibrated at the factory. This is a very important factor for the mines because the instruments are subject to errors depending on temperature, humidity, dust, vibration and impact, and may, therefore, require recalibration in the field.

To compare the advantages and disadvantages of noise dosimeters the following information was prepared (see Table 2).

1. Bendix 1150 Noise Exposure Monitor and 1100 Readout Unit can be used only for the measurement of low noise levels because of its low storage capacity: 0 to 255%. The

TABLE 2: Noise Dosimeters and Monitors

	Factory	Instrument	Weight	Range	115 dBA Exceeded	Accuracy	Microphone	Calibration	Power	Temp.	Humidity	Accessories
1.	Bendix National Environmental Instruments	1150 Noise Exposure Monitor, 1100 Read-out Unit.	0.227 kg	90 dBA to 115 dBA. 85 dBA provision is built in.	An automatic alert light turns on. Storage capacity: 0 to 255%.	ANSI S1.4-1971, Type S2A OSHA	Piezoelectric ceramic element. Non-directional.	1100 Readout Unit built-in calibration check of monitors.	2 x 9 V NEDA 1604 batteries. Life is 300 hr at 8 hr use per day.			
2.	Brüel and Kjaer	4425 Personal Noise Dose Meter, Type 4230 Calibrator.	0.280 kg	90 dBA to 115 dBA.	Read out by flashing led lamp during noise dose read-out. Storage capacity: 0 to 9999%.	ANSI S1.4-1971, Type S2A OSHA	Type 4125 condenser, omni-directional. Alternative remote mounting of microphone with optional preamplifier.	In calibration mode, 94 dB sound level at 1000 Hz will produce a display count rate of 1 per second.	2 x 9 V NEDA 1604 batteries. Life is 80 hr at 8 hr use per day.	-10°C to +50°C	0 to 90%	Clip-on microphone preamplifier with 1 m cable ZE0132. Tripod UA0049.
3.	Columbia Research Laboratories or General Scientific Equipment *	SPL-104AB Noise Dosimeter, SPC-14 Calibrator.	0.482 kg	90 dBA to 115 dBA.	A red miniature lamp turns on for a minimum one second. Storage capacity: 0 to 9999%.	ANSI S1.4-1971, Type S2A OSHA	Lead zirconate piezoelectric ceramic element. Semi-directional.	At 100 dB and at 114 dB, prefrd. freq. 125 Hz, 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz.	2 x 22.5 V NEDA 215 batteries. Life is 40 hr at 8 hr use per day.	-5°C to +60°C		Holster, CC-104, provides protection and allows instrument to be worn on a belt.
4.	E.I. du Pont de Nemours and Co. **	Audio Dosimeter and Audio Dosimeter Readout.	0.241 kg	90 dBA to 115 dBA.	Light emitting diode in dosimeter. Storage capacity: 0 to 3200%.	ANSI S1.4-1971, Type S2A OSHA	Ceramic Type Shure 99A401B, non-directional.	Factory calibrated - acoustically and electrically.	9V NEDA 1604 battery. Life is 80 hr at 8 hr use per day.	-18°C o +50°C		
5.	General Radio	GR 1944-1 Noise Exposure Monitor, GR 1944-1 Noise Exp. Indicator.	0.210 kg	80 dBA to 120 dBA	Information is stored in the monitor unit and read out on the indicators. Storage capacity: 0 to 999%.	ANSI S1.4-1971, Type S2A ISO R 1999 (May 1971)	Ceramic omni-directional microphone on extension cable.	GR 1944 Noise Exposure Indicator, built-in sound level calibrator.	9V Burgess 2U6 battery or equivalent 9V transistor battery. Life is 180 to 320 hr at 8 hr use per day.	-10°C to +50°C	Up to 90% RH at 40°C	
6.	Quest Electronics	M-6 Sound Hazard Integrator CA-10 Sound Level Calibrator.	0.709 kg	90 dBA to 115 dBA	An internal electronic latch is activated by short duration noise impulse above 115 dBA. Storage capacity: 0 to 999%.	ANSI S1.4-1971, Type S2A. OSHA	Ceramic omni-directional microphone with collar clip attachment and 3 ft of cable.	Sound pressure levels at 85, 90, 95, 100, 105, 110, 115 and 117 dB at frequency 1000 Hz ± 3%.	18 V NCB-18 replacement Ni-Cd battery or additional battery charger C1825.	-10°C to +50°C		Leather tamper-proof security case, model CS-4. Additional battery charger model C-1825.
7.	Triplett Electrical Inst.	Model 376 Personal Noise Dosimeter, Model 371 Sound Calibrator.	0.340 kg	90 dBA to 115 dBA	An alarm trips and latches on when the sound level exceeds 115 dB. The state of the 115 dB alarm is displayed by a red panel indicator. Storage capacity: 0 to 999%.	ANSI S1.4-1971, Type S2A. OSHA	Lead-zirconate-titanate ceramic unit connected to electronics by a 4-ft detachable coiled cable.	Sound pressure level 114 dB at 1000 Hz ± 3%.	9 V NEDA 1600 batteries. Life is approx. 200 hr of use, allowing for a 30-sec read-out cycle after every 8 hr of use.	-15°C to +50°C	5 to 85% RH	
8.	3M Company	NMI Monitor NCCI Charger/Calib.		90 dBA to 115 dBA		ANSI S1.4-1971, Type S2A. OSHA	Omni-directional microphone.		18 V NCB-18 replacement Ni-Cd battery.			
9.	Willson Products Division	IN-18 Sound Consultant Personal Unit, IN-17 Acoustic Calibrator.	0.339 kg	90 dBA to 115 dBA	An indicator on the readout unit will light. Storage capacity: 0 to 200%.	ANSI S1.4-1971, Type S2A. OSHA	Ceramic omni-directional microphone attached with 3 ft retractable cord	Sound pressure levels at 90 dB and 115 dB at frequency 1000 Hz ± 3%.	1 Ray-O-Vac #813 Alkaline-Manganese "D" cell (NEDA #13A). Life is 8 hr.	-15°C to +55°C	5 to 90% RH	

* Bausch and Lomb Optical Company Ltd. and Tracor Industrial/Medical Instruments products made by Columbia Research Laboratories Inc.

** The European version, the DuPont E-100 Audio Dosimeter and RE-150 Audio Dosimeter Readout, measures noise exposure between 80 and 115 dBA on the 3 dBA halving principle laid down in the ISO/R 1999 standard and British HM Factory Inspectorate Code of Practice.

instrument advantages are the following:

- built in acoustical calibrator,
- data in % exposure can be recalled from the monitor as often as desired prior to clearing the unit,
- memory consists of a rugged solid state printed circuit, and
- built-in battery life indicator.

The instrument disadvantages are:

- overrange light (> 115 dBA) gives the signal even if the noise level is < 115 dBA,
- sensitive to humidity and must be dried after use,
- instrument cannot be modified to 85 dBA in field, but in factory,
- the ceramic microphone (type Shure 99A401B) can be cleaned only by a qualified person, and
- life of batteries is 8 hours, but not 300 hours, use per day.

2. Bruel and Kjaer 4425 Personal Noise Dosimeter is a new instrument on the market. The instrument advantages are the following:
   - alternative remote mounting of the 1/2" condenser microphone with optional preamplifier,
   - instantaneous digital display reads directly in % of allowed exposure,
   - simple and accurate acoustic calibration with B and K Type 4230.

Calibrator, and accelerated measurement mode for short duration measurements (very important).

The instrument disadvantages are:

- instrument can be modified to an 85 dBA only in factory, and
- sensitive to impact if dropped.

3. Columbia Research Laboratories SPL-104AB Noise Dosimeter and SPC-14 Calibrator are similar technically and in appearance to the Triplett Electrical Inst. dosimeter. The Model SPL-104AB has a fixed microphone. The SPL-104 is provided with a microphone on an extension cable. It has extremely simple operation. The disadvantage of the instrument is that the microphone can be cleaned only by a qualified person.
4. E.I. du Pont de Nemours and Co. Audio Dosimeter and Audio Dosimeter Readout appeared on the market among the first. Since the beginning of this year (1974) in the European market, du Pont has sold this dosimeter. Dosimeter measures noise exposures between 80 and 115 dBA based on the ISO R1999 Recommendation (Table 2, footnote). Exposure is recorded on an electrochemical memory cell. The separate readout method provides the advantage that the dosimeter cannot be damaged by impact or vibration.

The primary disadvantages are:

- the monitor must be opened and the memory cell installed in the readout; the memory is cleared on readout and cannot be recalled,

- % exposure is obtained from the readout unit while cover must be removed from dosimeter to observe the overrange light,
- factory calibration,
- the dosimeter has the same microphone as Bendix and Columbia. For that reason only authorized personnel can clean the microphone.

5. General Radio GR 1944-I Noise Exposure Monitor, and GR 1944-I Noise Exposure Indicator in 1972 were the mark GR 1944 Noise Exposure Monitor and GR 1944 Noise Exposure Indicator. The microphone was very small and tended to gather dust and lint which affected its response. For this and other reasons, the instrument was redesigned by General Radio (Table 2). The instrument advantages are the same as Bendix.
6. Quest Electronics M-6 Sound Hazard Integrator and CA Sound Level Calibrator has a mechanical counter as opposed to an electronic counter. The monitor is integral with readout and is worn on the belt. Here also the disadvantage is the cleaning of the microphone and its sensitivity to impact.
7. Triplett Electrical Inst., Model 376 Personal Noise Dosimeter and Model 371 Sound Calibrator has the same construction as Columbia Research Laboratory's SPL 104AB dosimeter.
8. 3M Company NMI Monitor and NCCI Charger/Calibrator uses a remote microphone and a separate readout which has a

mechanical counter with a decimal place to measure tenths of a percent; however, this does not make the response more accurate. Only a qualified person can clean the microphone.

9. Willson Products Division IN-18 Sound Consultant Personal Unit has been on the market for a long time. Totally tamper-proof, the electronic memory cannot be erased until the disposable battery is replaced prior to the next use.

The instrument disadvantages are:

- sensitive to impact, and
- the microphone can be cleaned only by a qualified person.

There are many other instruments on the market but they are mainly similar to those displayed in Table 2. Edmont-Wilson, Division of Becton, Dickinson and Company sells a Sound Dosimeter Type 60-520 and sound level calibrator Type 60-530, which are the same as Quest Electronics Instruments.

On the European market there is also Computer Engineering Ltd. Noise Dosimeter (Type 122) besides Bruel and Kjaer and E.I. du Pont (12). The same type of dosimeter is available in the European market under the name of Optac Noise Dosimiter, mainly in West Germany (Glückauf, Feb. 1974). C.F. Casella and Co. Ltd., London, began with the production of the noise dosimeter.

4. PERSONAL NOISE EXPOSURE DOSIMETERS IN LITERATURE

In the U.S. the Noise Dosimeter appeared first in 1965. Since the Code of permissible noise exposures was published

TABLE 3

Response of Noise Dosimeters to Broad Band Noise as Percentage of Allowable Exposure Time* (14).

Level (dBA)	Dosimeter					
	A	B_1	B_2	B_3	C	D
87	0	0	-	-	0	0
	0	0	-	-	0	0
88	0	93	84	84	0	0
	0	89	89	89	0	0
89	0	89	89	89	0	0
	0	93	93	93	0	0
90	-	133	123	123	105	96
	135	130	124	119	107	95
91	136	133	118	118	109	96
	-	117	117	108	111	96
92	136	130	122	122	108	96
	104	128	125	119	111	96
93	132	139	131	131	112	95
	95	127	122	117	112	96
94	110	126	120	120	106	96
	114	130	103	130	109	95
95	103	125	113	119	107	94
	109	125	125	137	112	97
100	112	129	118	118	105	97
	113	130	120	120	105	97
105	139	117	117	112	102	100
	140	120	120	112	102	96

*Theoretically, all readings at 90 dBA or greater will be 100%.

in the Federal Register 1969 (U.S.) and adopted by ACGIH, several noise dosimeters have been marketed. In 1972 the first publication appeared with critical comment on noise dosimeters from different manufacturers (14). Tests for determining personal noise dosimeter response to broad-band noise were carried out in a reverberant room. The noise levels were checked with an octave band analyzer and graphic level recorder. The results for each noise level are reported in Table 3.

An analysis of variance for the various dosimeters tested disclosed a significant difference between the results. The same dosimeters were also placed in a tire test facility to determine their response to an industrial noise (Table 4).

TABLE 4

Dosimeter Response to Broad Band Industrial Noise (Tire Test Room) as Percent of Allowed Exposure (14).

Level (dBA)	Dosimeter					
	A	B_1	B_2	B_3	C	D
88	0	-	64	54	0	95
	0	-	52	59	0	90
89	-	96	102	102	-	94
	137	111	118	111	0	95
90	143	118	131	118	100	95
	138	115	130	121	100	95

These results indicate that some dosimeters would have reached 100% of the allowed exposure for less than 8 hours. Data on noise generated by wind on a dosimeter microphone and the effect of the position that the dosimeter microphone is worn by a worker are presented.

Almost at the same time M.W. Basch performed measurements on General Radio Company Pocket Noise Dosimeter (15). Tests were done in an anechoic chamber using a sine wave source. Results showed that the noise dosimeter can be a very accurate instrument even though it is small. In a reverberant room with reflective surfaces and using a noise generator as a source, the perturbations caused by body reflections are quite small, one to two dB. Thus the total accuracy including the effects of the body are comparable to a sound level meter. The dosimeter first was constructed to the Walsh-Healey Table or OSHA requirements. The instrument will not become obsolete when the law changes, because a provision for 85 dBA lower limit. The new instruments have to be built according to ISO R1999 or new OSHA requirements and procedures published in the U.S. Federal Register on October 24, 1974.

The British Code of Practice was prepared in 1971 by the Industrial Advisory Committee (16). This Code of Practice applies to all persons employed in industry who are exposed to noise and recommends limits to noise exposure. As the noise dosimeters are a recent development, there is no British Standard to which they conform and considerable variations are likely in the physical size, accuracy, power requirements, and convenience in use of different instruments.

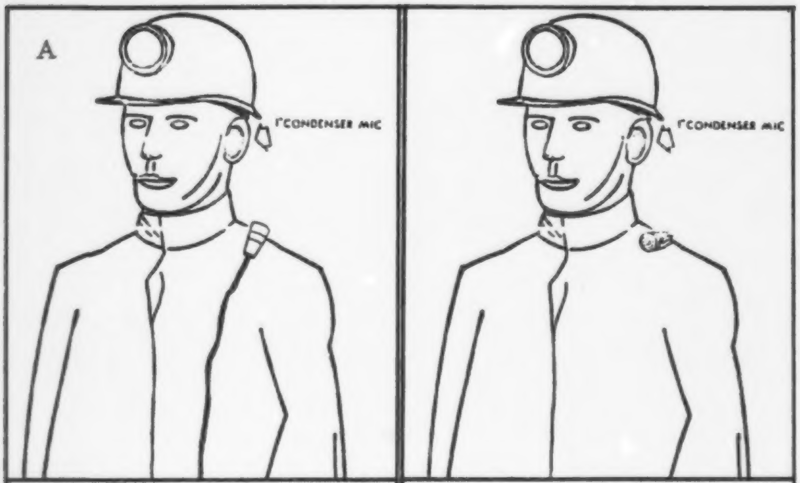
The Bureau of Mines conducted an investigation to evaluate microphone response variations that result when the noise dosimeter microphone is worn by a worker and to determine an optimum position and orientation of the microphone for noise exposure measurement (17).

Previous studies showed no significant differences in a diffuse field (14, 15). The USBM investigation was conducted in the free-field of an anechoic chamber using an anthropometric dummy (Figures 2 and 3). The results obtained using a dosimeter with the microphone located on the top of the subject's shoulders, oriented parallel to the body (Figure 2A), should be in agreement with those obtained using the standard sound-level meter.

Bruel and Kjaer Noise Dosimeter was submitted to strict examination during development in the laboratory and in an industrial environment. Body reflection effects were minimized by measurement at the ear position. Highly directional sound fields in the industrial cases produce errors which can be minimized in the same way (18).

The U.S. Department of Navy, Naval Aerospace Medical Institute, was interested in using personal noise dosimeters for estimating the noise exposure of military and civilian personnel (19). Three dosimeters of two types A and B were used for testing.

The tests were conducted in a reverberant room. The

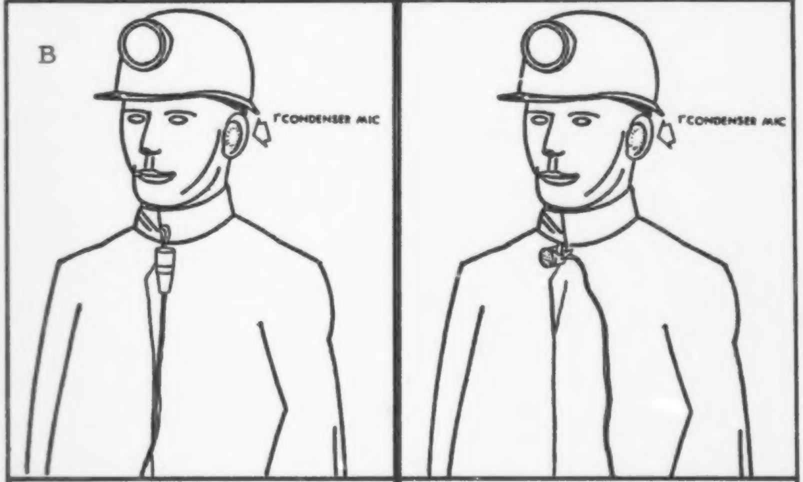


Microphone location: Top of the subject's left shoulder
Microphone orientation: Parallel to the subject
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	1.5	2.0	4.5	-3.5	-3.0
45°	3.0	3.5	3.5	-2.0	1.5
90°	3.0	3.5	.5	-1.5	.5
135°	1.5	1.5	.0	-2.0	.5
180°	.0	-1.5	-.5	-1.5	-1.5
225°	.0	-7.0	-3.5	-5.5	-5.5
270°	.5	-5.0	-2.5	-4.5	-8.0
315°	.5	-3.0	1.0	-2.0	-5.0

Microphone location: Top of the subject's left shoulder
Microphone orientation: Perpendicular to the subje
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	1.5	2.5	6.0	5.5	-0.5
45°	2.5	4.0	5.5	2.5	.0
90°	3.0	3.5	2.5	-3.0	1.0
135°	1.5	2.0	.5	-2.0	-3.0
180°	.0	-2.0	-.5	-1.0	-3.0
225°	-.5	-6.5	-3.5	-6.0	-6.0
270°	.0	-5.0	-2.5	-4.5	-7.5
315°	.0	-2.5	2.0	-.5	-3.5



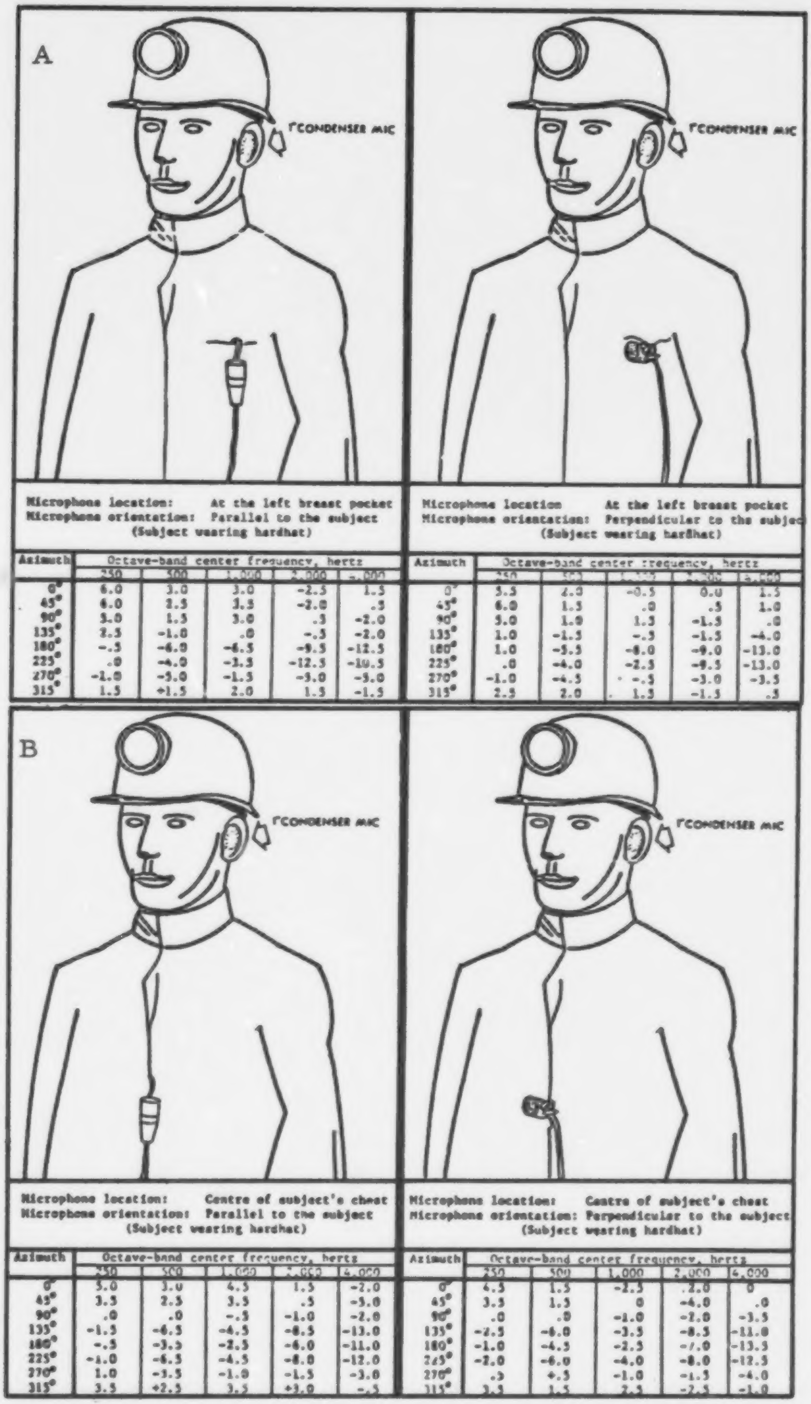
Microphone location: Between the collar tabs
Microphone orientation: Parallel to the subject
(subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	4.0	4.5	4.5	-1.5	-1.0
45°	3.0	3.5	5.0	3.0	-2.0
90°	.0	-1.0	1.0	1.0	-1.0
135°	-1.0	-6.5	-6.5	-7.0	-7.0
180°	-.5	-7.0	-7.0	-7.0	-13.0
225°	-1.0	-5.0	-3.5	-3.0	-7.5
270°	1.0	-1.5	±2.5	.5	-3.0
315°	3.5	4.5	4.5	-2.5	-.5

Microphone location: Between the collar tabs
Microphone orientation: Perpendicular to the subjec
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	4.0	5.0	0.5	-0.5	2.5
45°	3.0	4.0	3.0	-2.5	3.0
90°	.5	1.0	2.0	-1.0	-3.5
135°	-1.0	-6.0	-4.5	-4.5	-7.5
180°	-.5	-6.5	-7.0	-8.5	-11.5
225°	-1.0	-5.5	-4.5	-4.0	-9.5
270°	.0	.5	1.5	-.5	-3.0
315°	2.5	3.5	2.5	-2.5	1.5

FIGURE 2: Measuring Microphone:
A - At the top of the left shoulder,
B - Between the collar tabs.
Prepared by M. Savich from data by T. L. Muldoon (18).



Microphone location: At the left breast pocket
Microphone orientation: Parallel to the subject
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	6.0	3.0	3.0	-2.5	1.5
45°	6.0	2.5	3.5	-2.0	.5
90°	5.0	1.5	3.0	.5	-2.0
135°	2.5	-1.0	.0	-.5	-2.0
180°	-.5	-6.0	-6.5	-9.5	-12.5
225°	.0	-4.0	-3.5	-12.5	-10.5
270°	-1.0	-5.0	-1.5	-5.0	-5.0
315°	1.5	+1.5	2.0	1.5	-1.5

Microphone location At the left breast pocket
Microphone orientation: Perpendicular to the subject
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	5.5	2.0	-0.5	0.0	1.5
45°	6.0	1.5	.0	.5	1.0
90°	5.0	1.0	1.5	-1.5	.0
135°	1.0	-1.5	-.5	-1.5	-4.0
180°	1.0	-5.5	-8.0	-9.0	-13.0
225°	.0	-4.0	-2.5	-9.5	-13.0
270°	-1.0	-4.5	-.5	-3.0	-3.5
315°	2.5	2.0	1.5	-1.5	.5

Microphone location: Centre of subject's chest
Microphone orientation: Parallel to the subject
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	5.0	3.0	4.5	1.5	-2.0
45°	3.5	2.5	3.5	.5	-5.0
90°	.0	.0	-.5	-1.0	-2.0
135°	-1.5	-6.5	-4.5	-8.5	-13.0
180°	-.5	-3.5	-2.5	-6.0	-11.0
225°	-1.0	-6.5	-4.5	-8.0	-12.0
270°	1.0	-3.5	-1.0	-1.5	-3.0
315°	3.5	+2.5	3.5	+3.0	-.5

Microphone location: Centre of subject's chest
Microphone orientation: Perpendicular to the subject
(Subject wearing hardhat)

Azimuth	Octave-band center frequency, hertz				
	250	500	1,000	2,000	4,000
0°	4.5	1.5	-2.5	-2.0	0
45°	3.5	1.5	0	-4.0	.0
90°	.0	.0	-1.0	-2.0	-3.5
135°	-2.5	-6.0	-3.5	-8.5	-11.0
180°	-1.0	-4.5	-2.5	-7.0	-13.5
225°	-2.0	-6.0	-4.0	-8.0	-12.5
270°	.5	+.5	-1.0	-1.5	-4.0
315°	3.5	1.5	2.5	-2.5	-1.0

FIGURE 3: Measuring Microphone: A - At the left breast pocket,
B - At center of subject's chest.
Prepared by M. Savich from data by T. L. Muldoon (18).

noise source was broad-band noise shaped to be flat from 63 Hz to 8 kHz. The noise levels were monitored with a B and K Type 2203 sound level meter Type S2A, ANSI S 1.4 (1971). The tolerance is ± 3 dB up to 2 kHz and ± 6.5 dB at 8 kHz. Referring to Table 1, it can be seen that a difference of only a small number of decibels in the noise level has a great effect on conversion to a dosimeter exposure reading in percentage. The test for dynamic range shows striking differences at 100 dBA (Figure 4.1), for example, a reading of 130% is equivalent to a difference of only + 1.9 dBA and this is within tolerance (Table 1). The ability of the dosimeters to accumulate noise signals of various fixed levels and duration was shown to be within tolerance limits (Figure 4.2). One-hour exposure to Octave Band Centre Frequencies of noise showed all dosimeters were well within tolerance (Figure 4.3). However, in a one-hour Noise Burst Test, with 92 dBA background noise and 112 dBA noise bursts of 2-second duration occurring every ten seconds, it was seen that both types of dosimeters read higher than the expected 65 percent (Figure 4.4). Instrument A was outside the tolerance limit. The manufacturers claim that slow response characteristics have been built into the dosimeter circuits to the OSHA requirement. The readings obtained with the dosimeters from short duration noise will be higher than calculated values based on time and intensity.

In two industrial workshops the dosimeters were tested, obtaining test data as in Table 5.

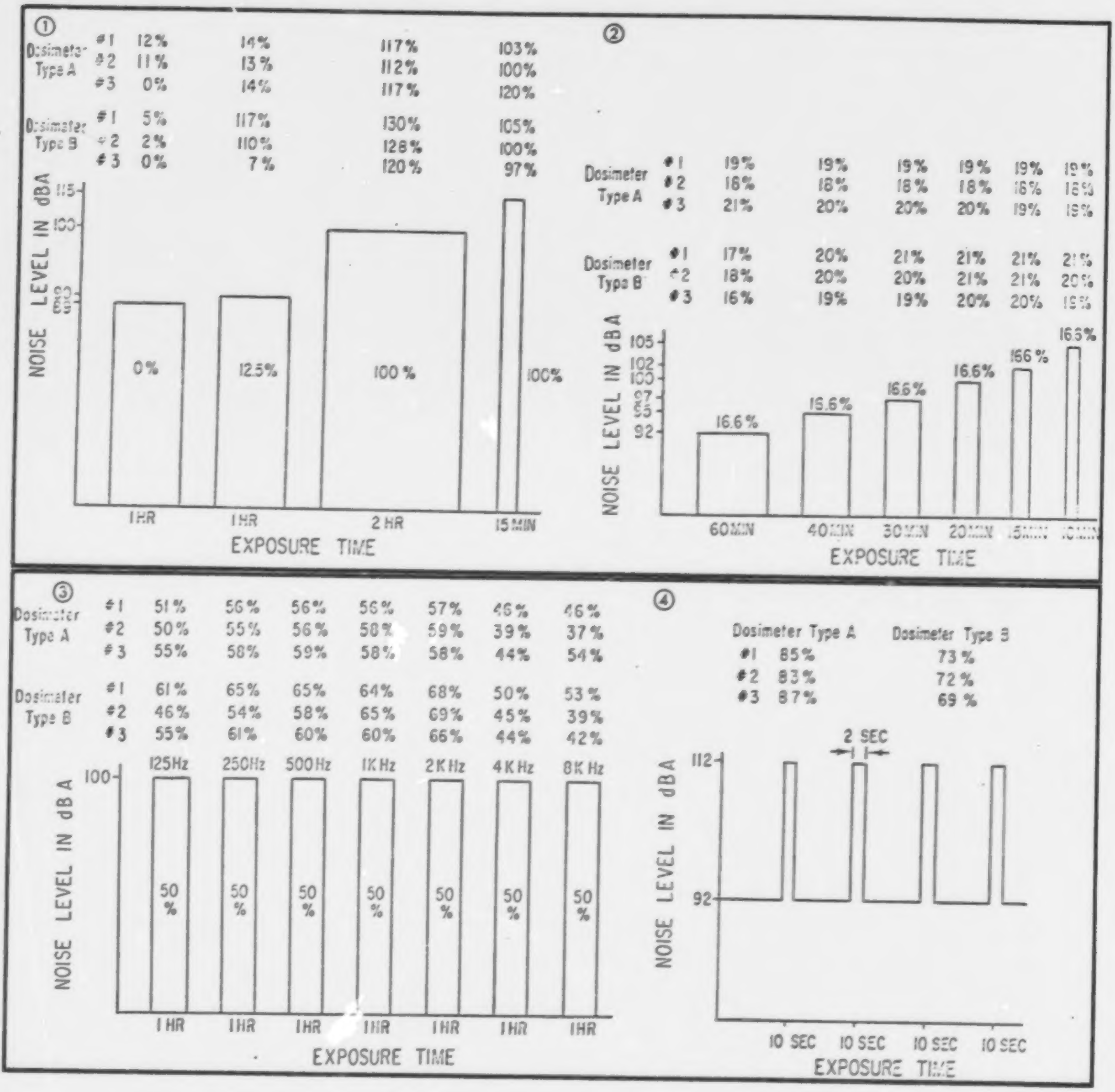


FIGURE 4: Performance Data of Noise Dosimeters (19).

1. Test levels for dynamic range.
2. Cumulative test for 100% total.
3. One-hour exposure to octave band of noise.
4. Noise burst test with 92 dBA background. Calculated one-hour exposure was 63%.

TABLE 5

Comparison of Acoustical Properties of Dosimeters, Monitors and Sound Level Meters

Instrument	Position	Noise Exposure in %	
		Workshop*	Sandblast Shop**
Dosimeter Type A	Ear	36%	31%
	Collar	57%	37%
	Pocket	100%	29%
Noise Monitors	5 ft from source	13%	38%
	5 ft from source	15%	36%
Sound Level Meter Type 1	5 ft from source	11%	109%

* Open workshop
** Reverberant

Prepared by M. Savich from data by J.R. Forstall and D.W. Maxwell (19).

These tests have shown that there are significant differences between different locations and different instruments.

Under the direction of the National Bureau of Standards and the Environmental Protection Agency, tests were conducted on noise exposure meters on the market today, to evaluate microphone and system response to sound of random incidence, frequency response, crest factor (Peak value/RMS value) capability, accuracy of the exchange rate circuitry, performance of the noise exposure meter as a function of temperature, and the dependence of the device on battery voltage (20). The test program has shown that a wide variation in performance exists among the noise exposure meters tested. It is evident that standards for these devices are an absolute necessity.

Under the direction of the Bureau of Mines, eight brands of personal noise dosimeters (including a prototype of a portable personal audio dosimeter from U.S.B.M.) were performance tested (21). All units met the A-weighting tolerance for Type 2 sound level meters, and six brands were within the Bureau's overall accuracy requirements of ± 2 dBA referred to input.

A short and very instructive paper was published in Sound and Vibration (22). A wide variation in performance has been observed among the various instruments. The tests were carried out to yield what was considered to be the most important information about the performance of each noise exposure meter. The overall performance of the noise exposure meters is shown in Table 6. The measurement uncertainty (95% confidence limits) for this test was estimated to be ± 10%. No performance standard exists for these devices, except the American National Standard Specification for Sound Level Meters, S1.4-1971, Type S2A, which is applicable to such instruments.

A pulsed sine wave was presented to the noise exposure meter using the voltage insertion technique to obtain a measurement of the crest factor handling capability. The crest factor of a signal is defined as the ratio of peak signal value to root-mean-square value (Peak value/RMS value). The response of the noise exposure meters as a function of crest factor normalized to 100% for a sine wave input are shown in Table 7. Most of the devices tested can handle small crest factors.

TABLE 6

Response of Noise Exposure Meters when Placed in a Field of Pink Noise at Sound Levels from 92 to 115 dBA (Response of 100 ± 10%) (22)

Model	Relative Response, Percent					
	Level of Sound Field, dB					
	92	95	100	105	110	115
A	123% 93%	116% 96%	117% 94%	82% 65%	82% 69%	80% 71%
B	105%	101%	103%	91%	92%	92%
C	103%	102%	105%	98%	97%	98%
D	93% 91% 111% 101%	95% 95% 114% 112%	97% 81% 108% 109%	99% 93% 111% 113%	100% 95% 112% 120%	95% 92% 111% 114%
E	93% 102%	95% 103%	103% 111%	100% 112%	100% 112%	96% 104%
F	89% 88%	100% 98%	96% 93%	95% 96%	89% 87%	81% 82%

TABLE 7

Response of Noise Exposure Meters as a Function of Crest Factor. Normalized to 100% for a Sine Wave Input (22).

Model	Relative Response, Percent				
	Sound Level, dBA	Crest Factor			
		1.414*	2	3	4
A	95 115	100% 100%	86% 78%	70% 51%	61% 35%
B	95 115	100% 100%	95% 107%	83% 98%	73% 73%
C	95 115	100% 100%	95% 91%	78% 74%	62% 49%
D	95 115	100% 100%	101% 101%	102% 102%	101% 101%
E	95 115	100% 100%	115% 115%	129% 96%	134% 70%

* Sine wave

On the basis of the performance tests, it is quite evident that a comprehensive performance standard for these devices is an absolute necessity to provide guidance on factors such as:

- microphone placement on the body,
- minimum recommended checks prior to usage, and
- handling procedures.

One practical application of General Radio Noise Exposure Monitor 1944-I to measurement of daily noise dose for employees wearing hearing protectors was published (23). The noise dosimeter with the remote microphone provides a simple and accurate means of measuring the incident noise at the ear, including the reduction by the hearing protectors. At NOISEXPO Conference 1974, two papers were presented: L.C. Marraccini (24) found the same results as T.L. Muldoon (17) and J. Donovan (25) repeated the results of L.S. Christensen (18).

It should be noted that in the literature the noise dosimeter and its application have often been mentioned but up to now a study of the technical use of the dosimeter in industry has not been done. The problems of applying noise dosimeters are still under study.

5. EVALUATION OF NOISE DOSIMETERS IN THE ELLIOT LAKE LABORATORY

In this laboratory brief but useful tests were conducted using two dosimeters: the Noise Dosimeter No. 1 and Noise Dosimeter No. 2. Both dosimeters belong to Type B (Figure 1).

5.1 Laboratory Tests

Tests were carried out in a constant-temperature semi-reverberant room 10 m long, 3 m wide, and 2.20 m high. The walls and ceiling were of wood construction, the floor was concrete and there were three windows and two doors in the room. There were not enough equipment and instruments to conduct a full test.

Some acoustical tests were performed using a pure sine wave at 1 kHz in the range from 92 to 110 dBA. The pure tone was generated by a Hewlett Packard Test Oscillator, Model 650A. The loudspeaker was oriented to eliminate directional effects and to achieve a diffuse noise field condition. The dosimeter microphones were suspended 1 m above the floor from ring stand clamps located in the middle room. The noise levels were observed with a sound level meter, B and K, Type 2205. All three instruments (both dosimeters and the sound level meter) conformed to the ANSI S1.4 (1971) specification for Type S2A sound level meters. The results indicated by the dosimeters after exposure for the test period were compared with the permitted exposure time for the sound level (Table 8).

All results of Noise Dosimeter No. 1 were within tolerance limits (Table 1).

An analysis of variance on the data obtained at various noise levels for the Noise Dosimeter No. 2 revealed a significant difference between sound level meter and dosimeter (Table 8). The instrument was returned to the company for modifications. After modification the instrument was tested in new semi-

TABLE 8

Response of Noise Dosimeters to a Pure Sine Wave at 1 kHz as a Percentage of Permissible Exposure Time

dBA at 1 kHz	Exposure Time, min.	OSHA		ISO R1999	
		B and K 2205 (%)	Dosimeter No. 1 (%)	B and K 2205 (%)	Dosimeter No. 2 (%)
92	30	12.5	10	17	22
95	30	13	18	25	38
97	30	17	19	33	51
97	30	--	--	33	53
97	30	17	18	33	46
97	30	17	18	33	62
97	30	17	20	33	56
97	30	17	20	33	51
97	30	17	20	33	52
100	15.2	13	15	25	41
102	15	17	21	31	60
102	15	17	21	31	57
105	15	25	31	50	82
105	15	25	29	50	85
110	15	50	60	100	169
110	15	50	56	100	173
110	15	50	54	100	173

reverberant room 4.25 m long, 4 m wide, and 2.5 m high. The walls, ceiling, and the floor were of wood construction and there was one window and door in the room. The room was empty.

According to factory data the instrument must correspond to the new OSHA recommendation or ISO Recommendation 1999, but the tests results show that the instrument did not satisfy either recommedndation. (Table 9).

Under the same conditions, acoustical tests were performed using a Bruel and Kjaer, Random Noise Generator, Type 1402 (Table 10).

TABLE 9

Response of Noise Dosimeter No. 2 to a Pure Sine Waves at 1kHz, 2kHz and 4kHz as a Percentage of Permissible Exposure Time

#	Noise Level in dBA	Exposure Time in minutes	Dosimeter No. 1 Reading in %			Expected Exposure in %	
			1kHz	2kHz	4kHz	ISO R1999	OSHA
1	90	30	1	0	0	~7.5	6.2
2			0	2	4		
3			0	0	0		
1	95	30	9	7	0	19.5	12.5
2			5	12	11		
3			7	9	12		
1	100	30	20	9	11	61	25
2			17	7	23		
3			16	7	18		
1	105	30	23	25	26	196	50
2			27	20	57		
3			23	24	17		
1	110	30	74	69	--	635	100
2			66	49	--		
3			66	49	--		

TABLE 10

Test Levels from 90 to 115 dBA for the same Time Range using a Noise Signal with Uniform Spectrum Density

#	Noise Level in dBA	Exposure Time in minutes	Dosimeter No. 1 Reading in %	Expected Exposure in %	
				ISO R1999	OSHA
1 2 3	90	30	0 0 0	~7.5	6.2
1 2 3	95	30	9 9 8	19.5	12.5
1 2 3	100	30	16 17 17	61	25
1 2 3	105	30	32 34 30	196	50
1 2 3	110	30	64 65 64	635	100
1 2 3	115	30	141 139 140	Over Exposed	200

The results from Table 10 show that the dosimeter is in full discordance with the results which were expected for ISO R1999 requirement. Therefore the test on this instrument was stopped.

5.2 Experimental Test of Employee Noise Exposure in Mines

The measurements were performed with three different instruments and three different methods of evaluation:

1. Sound Level Meter, B and K, Type 2205, standard method for testing noise exposure.
2. Noise Classifier, B and K, Type 166, which classifies noise levels into amplitude bands; the evaluation was performed by nomograms or tables.
3. Dosimeter No. 1, which automatically integrates the sound energy received.

The measurements were performed in underground mine conditions on the crusher, breaker, the Joy AL-60 Airleg and the Jarvis Clark Mine Jack 3M Jumbo.

Crusher

Instrument	21/08/73		22/08/73	
	Exposure Index	%	Exposure Index	%
Sound Level Meter B and K Type 2205	1.67	100	1.28	100
Noise Classifier B and K, Type 166	1.65	98.8	1.25	97.7
Dosimeter No. 1	1.74	104.2	1.97	153.0

On the first day of measurement, 21/08/73, the results were in agreement, but on the second day of measurement, 22/08/73, the dosimeter indicated a 50% higher exposure index, probably because of high humidity affecting the instrument accuracy.

Breaker

Instrument	23/08/73		29/08/73	
	Exposure Index	%	Exposure Index	%
Sound Level Meter B and K, Type 2205	(1.10)*	94	0.95	--
Noise Classifier B and K, Type 166	1.17	100	1.17	100
Dosimeter No. 1	1.07**	90.4	1.15**	98.3

* Estimated from the noise level value on 29/08/73 and the time 23/08/73.

** Not including drive exposure index, departure and arrival, 0.22.

The sound level meter was not used on 23/08/73 because it was out of order. The noise time according to hearing was measured and noise exposure index was calculated according to measurement data of 29/08/73. On 29/08/73 the noise classifier and dosimeter showed a higher exposure index because the place of measurement was changed from panel 16 to panel 12 and back again. At panel 12 a whole series of measurements was omitted because the sound level meter and microphone were fixed and therefore the result was lower.

The Joy AL-60 Air Leg

Instrument	31/08/73		05/09/73	
	Exposure Index	%	Exposure Index	%
Sound Level Meter B and K, Type 2205	2.16	100	2.61**	100
Noise Classifier B and K, Type 166	---	---	2.94	113
Dosimeter No. 1	2.32*	107	0.22	8.4

* Excluding drive exposure index, 0.08.
** Total duration in hours under 115 dBA. The duration over 115 dBA is 1.47 hours.

On 31/08/73 the Noise Classifier could not be included in the total measurement because no power supply was available. Evaluation of short duration noise measurements by the sound level meter during scraper work gave an exposure index of 0.38. On 05/09/73 the Dosimeter No. 1 gave a wrong result, perhaps because of high humidity or memory overflow. If we add 2.55+ to the result 0.22, we obtain 2.77 exposure index, which represents a good result.

Mine Jack 3M Jumbo, Jarvis Clark

Instrument	06/09/73		07/09/73	
	Exposure Index	%	Exposure Index	%
Sound Level Meter B and K, Type 2205	4.01	100	13.84*	100
Noise Classifier B and K, Type 166	4.11	102.5	13.76**	99.4
Dosimeter No. 1	1.48	~37	1.69	12

* The duration in hours over 115 dBA is 0.3994.
** The duration in hours over 115 dBA is 0.4567.

+ The maximum instrument reading is 225% (2.25).

In both measurements the dosimeter showed very low results. The most probable reason is memory overflow because the relative humidity was too low to affect the instrument.

Instrument	06/09/73		07/09/73	
	Exposure Index	%	Exposure Index	%
Dosimeter No. 1	1.48	37	1.69	12
Extended	2.55*	--	12.75**	--
Σ	4.03	100.5	14.44	104.3

* Memory overflowed once.
** Memory overflowed 5 times.

The results confirm that the cause was probably memory overflow. Ten measurements were performed in total. One measurement was omitted because of a power failure. Another set of measurements was omitted because the tests were made in a development drift and were not completed because of technical difficulties. In eight measurements the dosimeter showed four good and four bad results. The light-emitting diode array of the read-out device repeatedly indicated erroneously that the noise level was over 115 dBA.

During the period of the tests the technician was occupied with instrument cleaning and calibration, so that the measurements had to be interrupted periodically for one to two days. The sound level meter B and K Type 2205 and Noise Classifier B and K Type 166 showed approximate agreement. On 05/09/73 during testing of the Joy AL-60 Air Leg a slight difference was observed between the noise level meter and the 166 classifier, probably because the two microphones were not equidistant from the noise source.

6. CONCLUSION

An analysis of this report shows that there is a wide variation in performance amongst the various noise dosimeters tested. The system responses vary widely depending on the individual design. All noise dosimeters meet the tolerances for a specification for sound level meters, S1.4 (1971) Type 2A. Most instruments can tolerate only small crest factors (peak value/RMS value), but they suffer only a few percent error due to temperature effects and this is probably not critical. Industrial testing showed that highly directional sound fields which are often found underground can produce significant differences depending on microphone position. It might be necessary to provide guidance on such items as microphone placement as close to the ear as possible. As these instruments are a recent development, it is necessary to provide a comprehensive performance standard. American National Standards Institute Working Group S1-W45 is working on such a standard which should provide the following guidance (22):

a) microphone placement on the body,

b) minimum recommended checks prior to usage, and

c) handling procedures.

The published literature discusses extensively the question: what is a dosimeter and what are its performance limits? Until now there are only two publications on how to use it (23 and 27). There is no single publication which illustrates its use and the results obtained in the plant or mine.

The U.S. Department of Labor has proposed new occupational noise regulations with a lower limit of 85 dBA. Only two of the dosimeters could be adapted to this new standard.

An effort was made to develop the dosimeter for use in mines by designing the Noise Monitor Hat which should remove two main disadvantages of the dosimeter: variation in microphone placement on the body and lack of operating procedure guidelines (28).

7. ACKNOWLEDGEMENTS

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Performance analysis on noise dosimeters and noise exposure monitors

1975

Caractéristiques du dosimètre de bruit personnel de type 4425

Évaluation du numéro de série 453311

par

M. Savich*

RÉSUMÉ

Dans une étude en cours au Laboratoire d'Elliot Lake, nous essayons d'établir une méthode d'évaluation de la performance de dosimètres de bruit et d'appareils de surveillance du bruit. Nous étudions plus particulièrement la précision des instruments, l'emplacement du microphone et la relation entre les données obtenues au laboratoire et les mesures prises dans un environnement souterrain.

Nous avons évalué le dosimètre de bruit personnel Bruel et Kjaer, type 4425, numéro de série 453311. Nous avons observé qu'à bas niveau, l'intégration s'arrête à 92 dBa. Selon nos essais, le dosimètre personnel effectue le comptage lorsque le niveau de bruit est supérieur à 115 dBA. Toutefois, nous n'avons pas observé de différence importante entre les indications du dosimètre et les valeurs de l'exposition fournies par un sonomètre.

Bruit : Exposition : Dosimètre : Bruel et Kjaer : Précision

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Characteristics of the Personal Noise Dose Meter Type 4425 as Exemplified by Serial No. 453311

by

M. Savich*

ABSTRACT

In a study underway in the Elliot Lake Laboratory, we are attempting to establish procedures for testing the performance of noise dose meters and monitors, and to answer questions of accuracy, microphone placement, and how data obtained in the laboratory will relate to measurements in an underground environment.

A Personal Noise Dose Meter, Bruel and Kjaer, Type 4425, Serial No. 453311, was procured for evaluation. It was found that at the low-level end, the integration was inhibited at 92 dBA. According to our tests, the Personal Noise Dose Meter counts when the noise level is over 115 dBA. There was, however, no essential difference between the Dose Meter readings and exposure based upon sound level meter data.

Noise: Exposure: Dose Meter: Bruel and Kjaer: Accuracy

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1. INTRODUCTION

The Elliot Lake Laboratory is interested in the possibility of utilizing the Bruel and Kjaer (B and K) Type 4425 Personal Noise Dose Meter for testing ear muffs in underground environmental conditions. In a study in our laboratory, an attempt is being made to establish procedures for testing the performance of the noise dose meter using a precision sound level meter, B and K, Type 2203, ANSI* S1.4-61, to standardize the noise levels, and to answer the following questions:

1. What accuracy can be expected from the B and K Noise Dose Meter?
2. What are the effects of microphone placement?
3. How will data obtained in the laboratory relate to measurements in an underground noise environment?

The Noise Dose Meter may be of great advantage when making measurements to determine if the noise exposure is excessive. Criteria for occupational noise exposure can be found in the "Occupational Safety and Health Act" (OSHA)(Table 1).

TABLE 1

Noise Exposure Limits for a Normal 8-Hour Working Day

Noise Level (dBA)	Maximum Exposure (hr)
90	8
90-92	6
92-95	4
95-97	3
97-100	2
100-102	1.5
102-105	1
105-110	0.5
110-115	0.25
Above 115 dBA	None

---

* American National Standards Institute.

The criteria are based on measurements of the equivalent continuous noise level, Leq, provided the noise is not of an "impulsive" nature. Limits are based on tests showing that, for every halving of the duration of exposure, the intensity of exposure can be increased 5 dBA without an increase in the risk of noise-induced hearing losses. The A-weighted reading is used to estimate the probability of hearing damage in industry.

2. DESCRIPTION OF THE INSTRUMENT

The manufacturer claims that the Dose Meter complies with ANSI S1.4.1971 for Type 2 Sound Level Meter, which relates to automatic computation of noise exposure in accordance with OSHA requirements (Table 2).

TABLE 2

Total Tolerance Limits for Sound at Random Incidence for Type 2 Sound Level Meter

Frequency (Hz)	A-Weighting (dB)
31.5	+3.5, -4.0
63	+3.0, -3.0
125	+2.5, -2.5
250	+2.5, -2.5
500	+2.0, -2.0
1000	+2.0, -2.0
2000	+3.0, -3.0
4000	+5.5, -4.5
8000	+6.5, -6.5

The range of tolerance limits for Type 2 Sound Level Meter is from plus 3.5 dB or minus 4.0 dB in the low frequencies, to plus or minus 6.5 dB at 8000 Hz. The sound level tolerance limits are widest at 4000 to 8000 Hz, and the dose meter noise exposure percentage reading is greatly influenced by these limits, especially at the higher frequencies (Table 2).

A simplified block diagram of the Personal Noise Dose Meter, Type 4425, Serial No. 453311, is shown in Figure 1 (1).

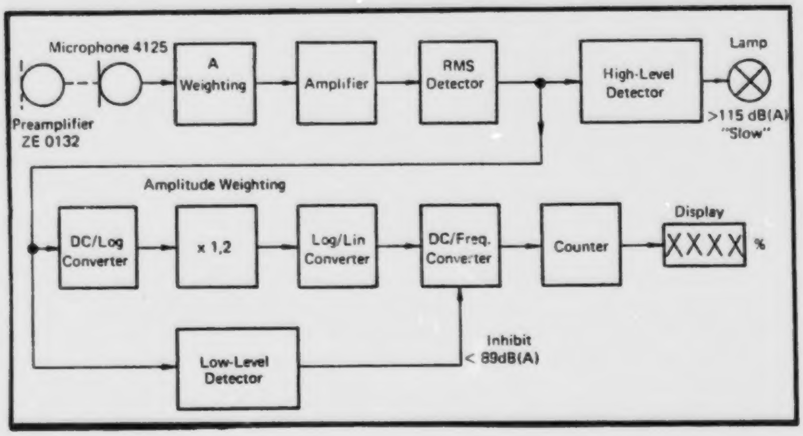
Microphone 4125
Preamplifier ZE 0132
A Weighting
Amplifier
RMS Detector
High-Level Detector
Lamp
>115 dB(A) "Slow"
Amplitude Weighting
DC/Log Converter
x 1,2
Log/Lin Converter
DC/Freq. Converter
Counter
Display
XXXX
%
Inhibit
< 89dB(A)
Low-Level Detector

Figure 1: Simplified Block Diagram of the Personal Noise Dose Meter (1).

2.1 Microphone

The half-inch condenser microphone, Type 4125, No. 442805, can be mounted directly on the Noise Dose Meter or separately using the Preamplifier ZE 0132 with a 1 m cable.

2.2 Input Circuits

The input circuits in the Noise Dose Meter are identical to those in the Sound Level Meter. The electrical signal from the microphone is passed first to an A-weighting filter. After A-weighting the signal is passed to an amplifier with a nominal gain of 30 dB. The gain of the amplifier is variable to allow adjustment for calibration purposes. The amplified signal is averaged in the RMS detector to give the "slow" sound level meter characteristic. The RMS detector is followed by two level-detectors and the amplitude weighting circuit.

2.3 Detectors

The DC signal is passed to a high-level detector (which operates only when the OFF/RESET switch is in the "ON" position) for detection of levels in excess of 115 dBA Slow. A light shows when 115 dB A-weighted sound level has been exceeded.

The low-level detector inhibits measurement below 89 dBA in accordance with the OSHA criterion. The use of low-level inhibition greatly reduces the integrator drift (which is usually a problem with integrator circuits) so that only straight forward drift compensation is required in the instrument (2).

2.4 Amplitude-Weighting Circuitry

Research has shown that, in practice, doubling the pressure more than doubles the damage potential. The Personal Noise Dose Meter must take this influence into account, the process being known as "amplitude weighting", by raising the sound pressure to some power. The following formula represents the evaluation of a noise dose (ND) (2):

$$ND = 100\int_0^T \left[\frac{P(t)}{0.632}\right]^n dt\% \qquad \text{(Eq 1)}$$

where: P(t) is the A-weighted time-varying sound pressure in pascals (Pa),
T is the measurement duration in hours,
0.632 Pa is the pressure corresponding to 90 dBA, and
t is the time in hours.

Under the OSHA criterion an increase in the sound level of 5 dBA reduces the permissible exposure period by one half (q = 5 in Figure 2). It follows that the noise dose for 95 dBA for 4 hours is equivalent to that for 90dBA for 8 hours:

$$\int_0^4 \left[\frac{1.124}{0.632}\right]^n dt = \int_0^8 \left[\frac{0.632}{0.632}\right]^n dt \qquad \text{(Eq 2)}$$

where: 1.124 Pa is the pressure corresponding to 95 dBA.

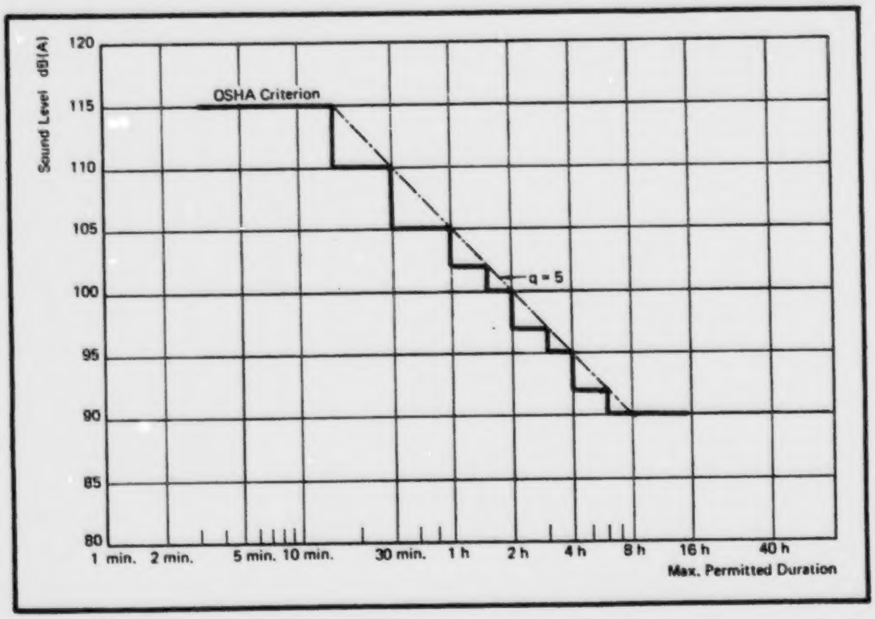

Figure 2: Relationship between Sound Level and Maximum Permitted Duration (OSHA).

Integration gives:

$$[1.780^n.t]_0^4 = [1^n.t]_0^8 \qquad \text{(Eq 3)}$$

or,

$$1.780^n . 4 = 8$$

$$1.780^n = 2$$

$$1.780^{1.2} = 2$$

therefore, $n = 1.2$

Thus, under OSHA with a q = 5 from Eq 1,

$$ND_{OSHA} = 100 \int_0^T \left[\frac{P(t)}{0.632}\right]^{1.2} dt\% \qquad \text{(Eq 4)}$$

2.5 Integration

From the amplitude-weighting circuitry the DC signal is passed to a DC/frequency converter. This integration technique is a common feature of analog computers. The low-level detector inhibits measurement below 89 dBA following the OSHA criterion.

The counting circuitry stores the accumulated noise dose count with the maximum indication of the display 9999%. The display is reset to 0% by switching the OFF/RESET switch to "Off" for at least 5 seconds and then switching to "On" or "Cal" (for calibration) as required.

In the "Cal" mode the noise dose meter counting rate is increased relative to the "On" counting rate. This increase is given as follows:

$$C_{On} = \frac{1}{166} C_{Cal} \ (\%) \qquad \text{(Eq 5)}$$

where: C_{On} is a count in the "On" mode,

C_{Cal} is the equivalent count in the "Cal" mode.

The sound level range for "On" is 89 to 115 dBA Slow, and for "Cal" is 87 to 113 dBA Slow.

The calibration is made so that the Noise Dose Meter will count at a rate of 1% per second when a 94 dBA sound source (sound level calibrator, B and K, Type 4230) is applied. The Noise Dose Meter is supplied with two 9 V cells (IEC 6F22); the cell life is 50 hours under continuous use with the switch in the "On" position, and 30 hours for continuous use in the "Cal" position.

3. PERFORMANCE DATA FOR THE NOISE DOSE METER

Tests were carried out in a constant-temperature semi-reverberant room 4.25 m long, 4 m wide and 2.5 m high. The walls, ceiling and the floor were of wood construction and there was one window and one door in the room. The room was empty.

Under the same conditions, acoustical tests were performed using a Bruel and Kjaer, Random Noise Generator, Type 1402 and a Hewlett-Packard Test Oscillator, Model 650A. The high-powered loudspeaker was oriented to eliminate directional effects and to achieve a diffuse noise field condition. The noise dose microphone was suspended 1.3 m above the floor from ring stand clamps located in the middle of the room.

3.1 The Effect of dBA Variation on Percentage Readings

Tolerance limits for Type 2 Sound Level Meters are specified by a standard for measurement of OSHA compliance (Table 2). The effect of dBA variation on percentage reading was derived from Table 1 and Table 2 (Table 3).

TABLE 3

The Effect of dBA Variation on % OSHA Exposure Measurement

dBA Error	% Reading (When Expecting 100%)
+6.5	246.2
+6.0	229.7
+5.5	214.4
+5.0	200.0
+4.5	186.6
+4.0	174.1
+3.5	162.4
+3.0	151.6
+2.5	141.4
+2.0	132.0
+1.5	123.1
+1.0	114.9
+0.5	107.2
0	100.0
-0.5	93.3
-1.0	87.1
-1.5	81.2
-2.0	75.8
-2.5	70.7
-3.0	66.0
-3.5	61.6
-4.0	57.4
-4.5	53.6
-5.0	50.0
-5.5	46.7
-6.0	43.5
-6.5	40.6

The relationship of the dBA error scale and the percentage reading scale is that 5 dBA doubles the percentage reading (OSHA). Ideally the input signal spectrum should be representative of "mine" noise. A calculation was done using "pink noise" from 20 Hz to 10,000 Hz for the input signal spectrum.

Spectra were computed for the A response and again for the upper and lower limits for Type 2 tolerances. The results show that the dBA value deviates from +3.4 dBA to -2.1 dBA from the correct pink noise level (3). Therefore, for every result, if we are expecting 100% noise exposure, between 75% and 160% will be acceptable (Table 3).

3.2 Test Data for Dynamic Range

The test for dynamic range was conducted in the "Cal" mode, with the microphone Type 4125 mounted on the clip-on preamplifier ZE 0132 (Figure 3). At 89 and 90 dBA the readings were zero; at 91 dBA the noise dose meter counted extremely low. Readings at 95, 100, 105 and 110 dBA were within tolerance. The test at a maximum level of 115 dBA resulted in maximum error of 22%, but the range for "Cal" was 87 to 113 dBA Slow. Lower levels did not correspond to the factory's claims. During the high level noise testing, the preamplifier ZE 0132 broke down. After this test, the microphone Type 4125 was mounted directly on the noise dose meter.

The same test was repeated with a condenser microphone Type 4125 mounted directly on the noise dose meter (Figure 4). The reading at the 90 dBA level was once again zero. Other readings were within tolerance.

3.3 Accumulative Test for 100% Total

This test was carried out to evaluate the ability of the Noise Dose Meter to accumulate noise signals of various fixed levels and durations (Figure 5). The sound level was controlled in each interval to correspond to a 16.6 percent exposure. In the "Cal" mode all readings were within tolerance. In the "On" mode the reading at 92 dBA was zero. Other readings were within tolerance.

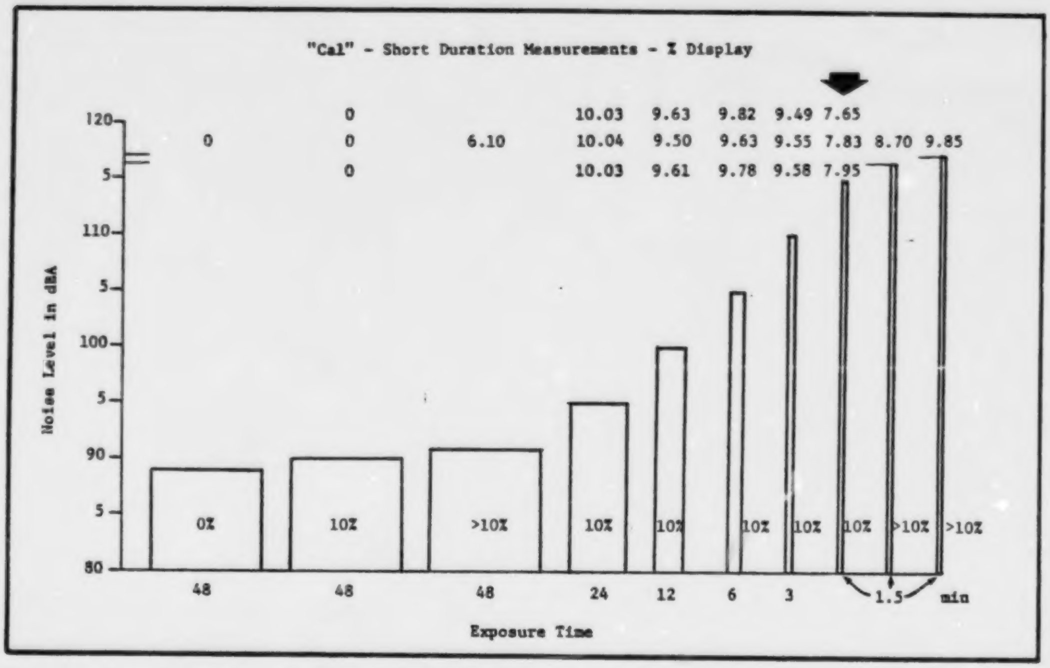

Figure 3: Test Level for Dynamic Range.
(Alternative mounting of microphone Type 4125 on clip-on preamplifier ZE 0132 which connects to Noise Dose Meter via 1 m cable.)

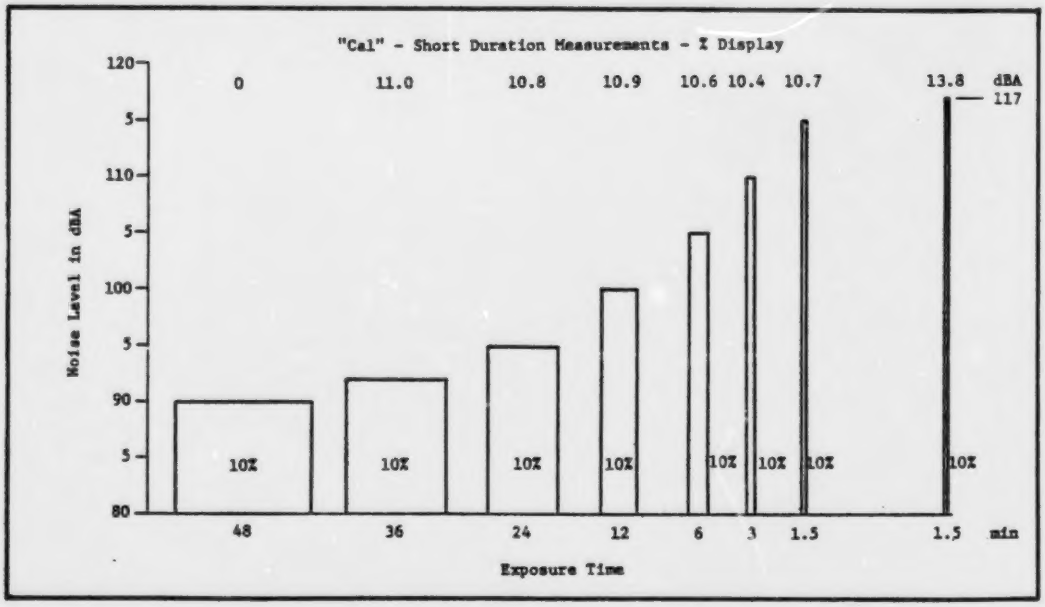

Figure 4: Test Level for Dynamic Range.
(Condenser Microphone Type 4125 mounted directly on Noise Dose Meter.)

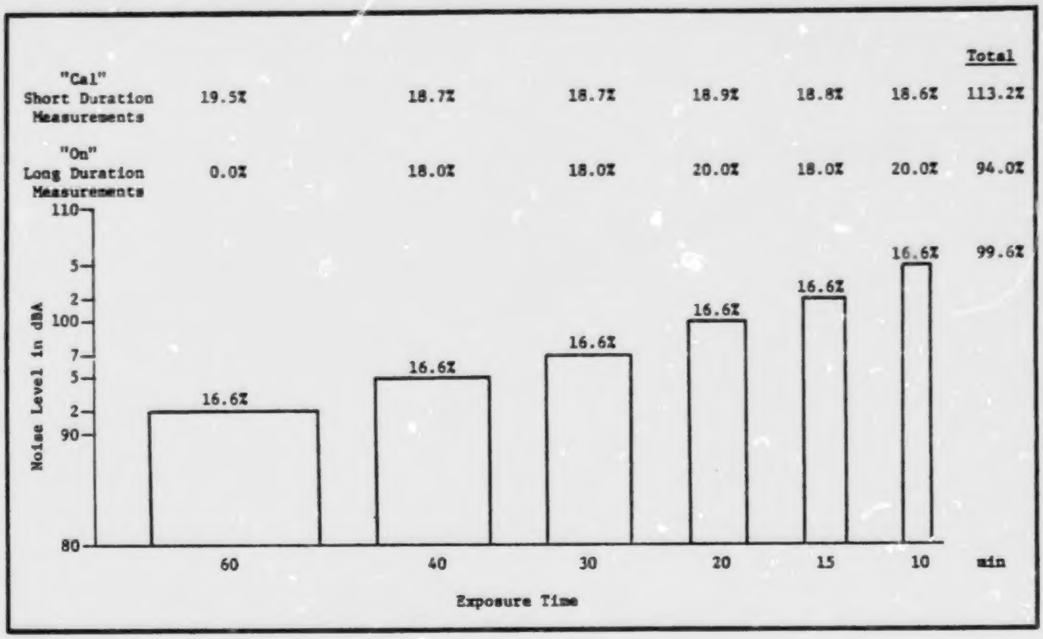

Figure 5: Accumulative Test for 100% Total.
(Condenser Microphone Type 4125 mounted directly on Noise Dose Meter.)

3.4 Exposure Test to Octave Bands of Noise

The Dose Meter was exposed to octave bands of noise at 100 dBA for one hour each except for 8 kHz (95 dBA). Each exposure except the last corresponds to a 50% exposure according to the OSHA criterion. The exposure at 95 dBA corresponds to 25% (Figure 6). Examination of the test data showed the 8 kHz band to have the greatest error.

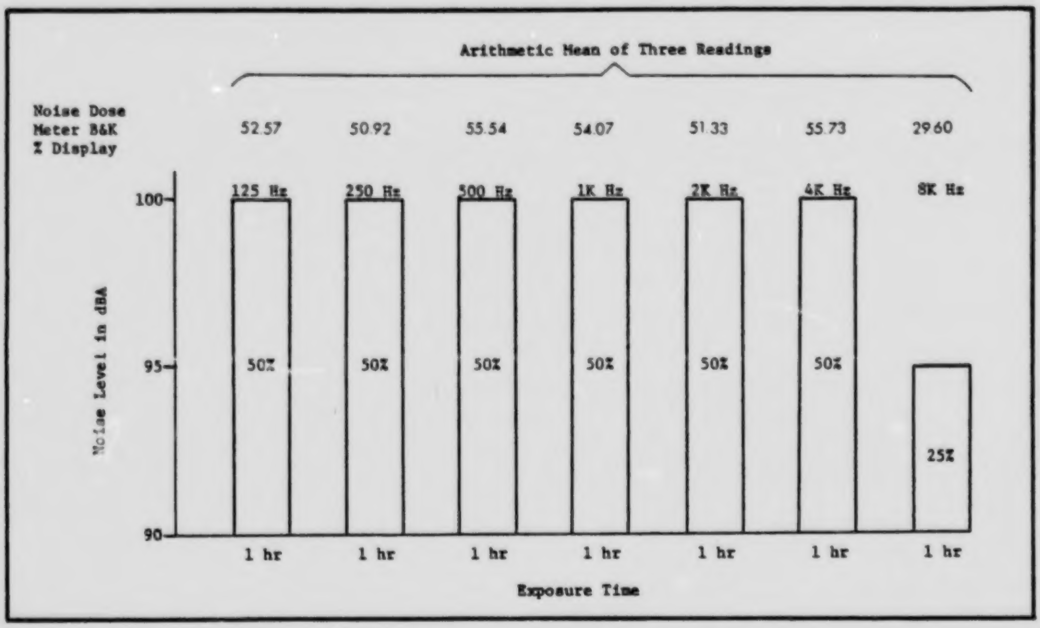

Figure 6: One-Hour Exposure to Octave Bands of Noise. (Condenser Microphone Type 4125 mounted directly on Noise Dose Meter.)

3.5 Noise Burst Test

The noise burst test was performed to investigate the effects of intermittent noise peaks (Figure 7). The background level on the storage circuits of the Noise Dose Meter was 97 dBA with 115 dBA pulses of 2-seconds duration after every ten seconds; 30 minutes produces 47.2% exposure. OSHA has established the A-scale at slow response characteristic of a sound level meter as the criterion for measuring noise levels. It was believed that results obtained with the Noise Dose Meter from short duration noise pulses may be lower than calculated values of time versus intensity. The results for both modes of measurements are within tolerance. The test was repeated many times and showed the high quality of the instrument.

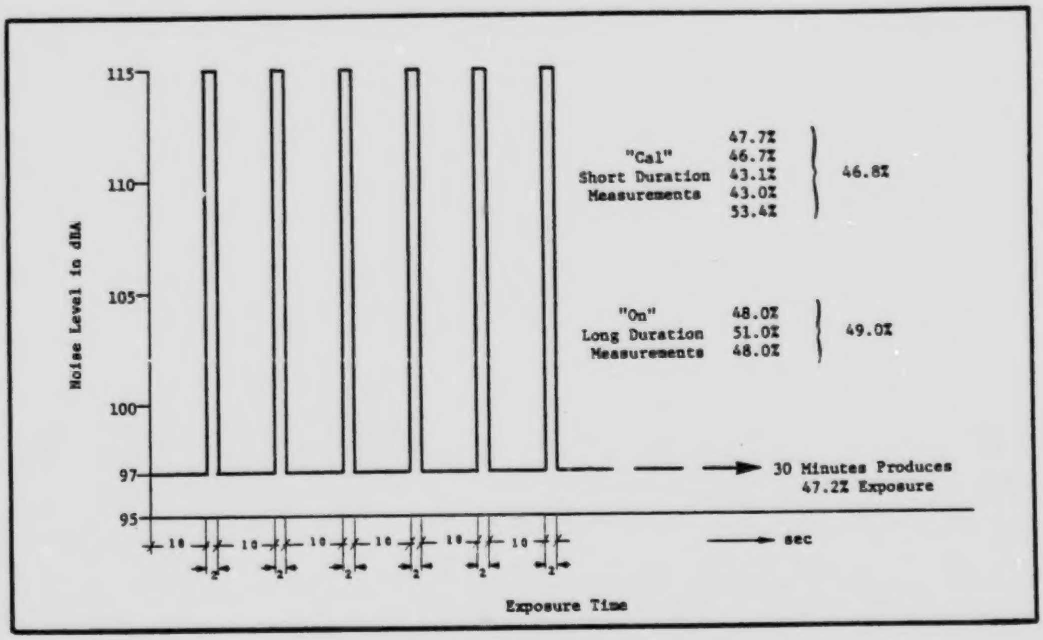

Figure 7: Noise Burst Test with 97 dBA Background. (Condenser Microphone Type 4125 mounted directly on Noise Dose Meter).

3.6 Errors of Microphone Position

Industrial testing showed possible errors due to body shielding and reflection effects (4). Industrial tests also showed that highly directional sound fields can produce differences depending upon the microphone position. The Personal Noise Dose Meter should be mounted near the operator's ear.

4. CONCLUSIONS

1. The low-level detector should be improved. B and K claim inhibition of <89 dBA (Figure 1), but this was not correct. The integration was inhibited at 92 dBA (see Figures 3, 4 and 5).

2. For sound level range the factory claims: "90 dBA to 115 dBA in accordance with OSHA requirements (to 125 dBA including 10 dB crest factor allowance at 1 dB error)". Our tests confirmed that the Personal Noise Meter counts over 115 dBA (Figures 3 and 4); it would, however, be better if the upper limit was 115 dBA because of simpler interpretation of results. Any exposure reading over 115 dBA is insignificant compared to the fact that a permissible limit has been exceeded. It is clear that only a qualified person can carry out the test procedures and clarify results.

3. The tests showed that there were no essential differences between the Dose Meter readings and calculated exposure based upon sound level meter data.

5. ACKNOWLEDGEMENTS

B. Brownlee and B. Fulcher, Bruel and Kjaer Canada Limited, Bramalea, Ontario, are thanked for lending the Personal Noise Dose Meter to be tested. Dr. Gibbs, Director of Occupational Health and Safety Unit, Institute for Mineral Industry Research, McGill University, lent the Random Noise Generator, amplifier and loudspeaker for testing.

The author acknowledges the contribution of R. Tervo, Research Scientist, Elliot Lake Laboratory, and of H. Montone and R. Regan who provided technical assistance.

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VOL.1 Report 6

75-23 M. Savich

Characteristics of the personal noise dose meter type 4425 as exemplified by serial no. 453311

1975

Méthode simple d'évaluation de l'indice d'exposition au bruit et du niveau sonore continu équivalent

par

M. Savich*

RÉSUMÉ

Pour évaluer l'exposition au bruit dans les mines, il convient de disposer d'une méthode utilisable par des personnes qui n'ont pas de formation technique particulière en acoustique.

Une méthode graphique a été mise au point pour l'évaluation de l'indice d'exposition au bruit, selon les critères de l'Occupational Safety and Health Act, et du niveau sonore continu équivalent. Dans cette méthode, on utilise une formule de relevé du bruit et un intégrateur mécanique comportant deux coulisses. Deux exemples de mesure pratique sont donnés afin d'illustrer la méthode. Les résultats sont presque identiques à ceux obtenus à l'aide des méthodes numériques ordinaires.

La méthode d'évaluation est universelle et peut être appliquée à tous les codes, dans toutes les situations et avec tous les instruments.

Indice d'exposition au bruit : Niveau sonore continu équivalent : Évaluation : Formule de relevé du bruit : Intégrateur mécanique

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Simple Method of Evaluation of the Noise Exposure Index and the Equivalent Continuous Sound Level

by

M. Savich*

ABSTRACT

In making an assessment of noise exposure in mines, a procedure is required that can be used by persons who do not have technical training in acoustics.

A graphical method has been developed for the evaluation of the Occupational Safety and Health Act Noise Exposure Index and the Equivalent Continuous Sound Level. The method makes use of a Noise Survey Form and a Mechanical Integrator with two sliders. Two examples of a practical measurement are given to demonstrate the procedure. The results are almost identical to those obtained by standard numerical methods.

The method of evaluation has universal application for all codes, all situations and all instruments.

Noise Exposure Index: Equivalent Continuous Sound Level: Evaluation: Noise Survey Form: Mechanical Integrator

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1. INTRODUCTION

Those who apply OSHA* regulations and codes would like to obtain precise measurements quickly via the use of inexpensive instruments; use of inexpensive instruments requires long manual numerical manipulations, especially in the case of the OSHA Noise Exposure Index.

To avoid this problem, a simple method is proposed for calculating the OSHA Noise Exposure Index and the Equivalent Continuous Sound Level by means of a graphical method. The Equivalent Continuous Sound Level evaluation is based on measurements made during sample periods. The methods suggested have universal application for all codes, all situations and all instruments.

2. OBJECTIVE OF NEW EVALUATION METHODS

The objective of this study was to evaluate the Noise Exposure Index and the Equivalent Continuous Sound Level, L_{eq}.

2.1 Occupational Noise Exposure

The permissible noise exposures from the OSHA regulation are given in Table 1.

---

* The Occupational Safety and Health Act (U. S. A.).

TABLE 1

Noise Exposure Limits for a Normal 8-Hour Working Day

Band	Noise Level (dBA)	Maximum Exposure (hr)
A	90	8
B	90-92	6
C	92-95	4
D	95-97	3
E	97-100	2
F	100-102	1.5
G	102-105	1
H	105-110	0.5
J	110-115	0.25
	Above 115	None

When the noise consists of different levels throughout the day, their combined effect is considered as follows:

$$\Sigma C/T = (C_A/8 + C_B/6 + C_C/4 + C_D/3 + C_E/2 + \ldots + C_J/0.25) \qquad \text{(Eq 1)}$$

where $\Sigma C/T \leq 1$ is the OSHA Mixed Exposure Index, and C_A is the total time the noise level is in band A, C_B is the total time the noise level is in band B, etc.. These limits are based on tests showing that, for every halving of the duration of exposure, the intensity of exposure can be increased 5 dBA without an increase in the risk of noise-induced hearing losses. The A-weighted reading is used to estimate the probability of hearing damage in industry.

2.2 Continuous Exposure

The value of the Equivalent Continuous Sound Level, L_{eq}, can be based on measurements made during sample periods (less than 8 hours). In practice, measurement over the whole working period will not usually be needed.

L_{eq} is defined mathematically by (1):

$$L_{eq} = 10 \log \frac{1}{T_s} \int_0^{T_s} \frac{\left[P_A(t)\right]^2 dt}{P_0^2} \qquad \text{(Eq 2)}$$

where: T_s is the total sampling period in hours,

P_A is the instantaneous A-weighted sound pressure in Pa (pascal),

P_o is the reference r.m.s. sound pressure, 2×10^{-5} Pa, and

t is the time in hours.

When the sound level is steady, L_{eq} is equal to the reading of a sound level meter. When the sound level is not constant, there is no instrument available to indicate L_{eq} directly.

The Equivalent Continuous Sound Level can be obtained from a nomogram or can also be calculated from Tables. Calculations of the Equivalent Continuous Sound Level are possible from the results of a statistical analysis, by using statistical analyzers with a class width of 5 dBA or 2.5 dBA (1).

Finally, calculators for evaluating the Equivalent Continuous Sound Level are on the market (2, 3 and 4).

2.3 Instruments

The basic instruments for noise measurement and for measuring noise exposure are:

1. Sound level meter, a stopwatch and a data sheet for full-shift information;
2. Statistical analyzer to provide data for a manual analysis based on partial shift information.

3. Graphical level recorder to provide a continuous record of the r.m.s. sound pressure level versus time for full-shift information;
4. Noise dose meter to automatically integrate the sound energy received, allowing simple calculation of the equivalent continuous sound level to determine only the exposure index.

The first three instruments require lengthy numerical evaluation which requires attention.

3. PROCEDURES FOR MAKING ASSESSMENT OF THE NOISE EXPOSURE INDEX AND EQUIVALENT CONTINUOUS SOUND LEVEL

3.1 Evaluation of the Noise Exposure Index

For fast and simple evaluation of the Noise Exposure Index an OSHA Noise Survey Form is made (Appendices 1 and 2) and the Mechanical Integrator with two sliders (Appendix 3) is used. Instead of the Mechanical Integrator, an ordinary ruler or a piece of paper can be used. Such simple devices, however, have to be discarded or cleaned after a number of markings have been made on them; thus they are not practical.

The results of measurement of noise levels versus time are put into the noise survey form, and the exposure value for each level is read on the upper horizonontal line of the form. The exposures are added with the Mechanical Integrator and the total exposure is read off on the upper scale (Figure 1).

If the exposure is greater than 100%, slider No. 1 is used as a marker for the excess over 100% and the adding is continued. If the exposure is greater than upper limit of the form, the complete hundreds are entered in the column "Over 100%", and the remainder is recorded in the table. These values are added upon the final integration of the exposure value.

The total time is obtained directly from numerical data or is read from the instrument used. Evaluation can be done directly from the form used for calculating the OSHA mixed exposure index with the Mechanical Integrator. An integrator is placed on the lowest horizontal edge of the table. The time is read from the table and the timed values of each level are added using slider No. 2. Slider No. 1 is used as a pointer to aid in the addition (Appendices 1 and 2).

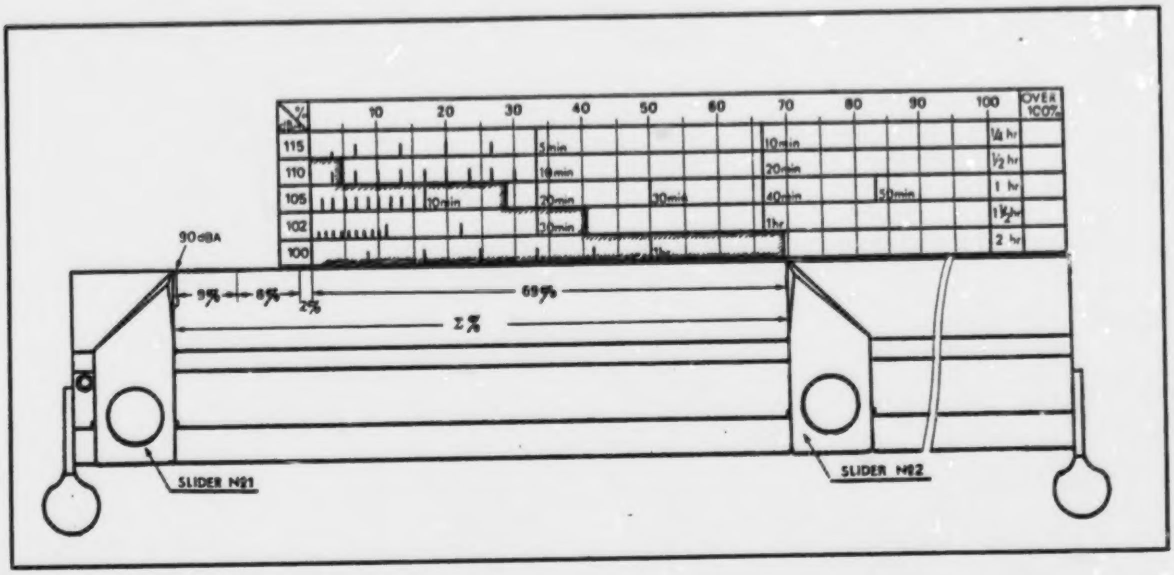
%
dBA
10
20
30
40
50
60
70
80
90
100
OVER 100%
115
110
105
102
100
5min
10min
30min
10min
20min
40min
50min
20min
30min
1hr
¼ hr
½ hr
1 hr
1½ hr
2 hr
90dBA
9%
8%
2%
69%
Σ%
SLIDER Nº1
SLIDER Nº2

Figure 1: Method of Calculating OSHA Mixed Exposure Index.

3.2 Evaluation of the Equivalent Continuous Sound Level

From the form, "Method of Calculating OSHA Mixed Exposure Index", the values of permissible exposure in percent and time in hours and minutes, are transferred onto a nomogram, "Method of Calculating Equivalent Continuous Sound Level". The nomogram consists of three parallel scales so graduated that a straight line which joins gradations on two of the scales will cut the third scale at a value which satisfies an equation of the form: $$f_1(u) + f_2(v) = f_3(w) \qquad \text{(Eq 3)}$$

In our case, instead of the sum we have the product of two functions; therefore the following equation results (see Eq 2):

$$f_1(u) \times f_2(v) = f_3(w) \qquad \text{(Eq 4)}$$

Taking logarithms, we have:

$$\log f_1(u) + \log f_2(v) = \log f_3(w) \qquad \text{(Eq 5)}$$

and we have an equation of the same form as Eq 3.

In our nomogram the inner scale is equally distant from the two outer scales, an arrangement often employed. The evaluation and the drawing of the scale were done in accordance with suggestions from the literature (5,6).

If the noise exposure is greater than 4000%, it is necessary to divide the percent of permissible noise exposure and the time by the same number. The results are marked in the nomogram and the equivalent continuous sound level can be read directly. Also, if the noise exposure time is less than one minute, it is necessary to multiply the time and the percent of permissible noise exposure by the same number, and thus with the result entered into the nomogram the equivalent continuous sound level can be evaluated.

4. ACCURACY OF THE GRAPHICAL METHOD

The basic demand is geometric accuracy during the drawing of the scale. Scales are drawn to let the human eye have easy and maximum surveillance of the information. The normal eye is capable of seeing spaces of 0.1 mm but it has limited capabilities when it comes to interpolation.

Two extreme cases were reviewed in underground mines: crusher and jumbo drill (Appendices 1 and 2).

4.1 Crusher

The results obtained using the graphical method of calculating the OSHA Mixed Exposure Index and the Equivalent Continuous Sound Level should be comparable with those obtained using the standard method of calculation (Table 2).

TABLE 2

Comparison of Results of Noise Exposure Index at the Crusher Operator's Ear

Method of Calculating	Exposure Index	Leq (dBA)	ΣTime* (hr)
Standard	1.67	100.6	3.31
Graphical	1.65	100.3	3.25

* exposure period

The results of the Exposure Index and the Equivalent Continuous Sound Level were almost the same for the two methods. The Equivalent Continuous Sound Level result from the graphical method was only about 0.3 lower than that obtained from the standard method. Total exposure time was 4 minutes less with the graphical method. The difference has no effect on the result.

4.2 Jumbo Drill

Two jumbo machines with two booms each worked continually during the measurements of noise (Table 3).

TABLE 3

Comparison of Results of Noise Exposure Indices at the Jumbo Drill Operator's Ear

Method of Calculating	Exposure Index	L_{eq} (dBA)	ΣTime* (hr)
Standard	12.47	113.16	4.33
Graphical	12.43	113.2	4.22

* exposure period

The results were the same. The total exposure time was 6.5 minutes lower using the graphical method. In both cases, the results were almost the same as with those obtained by standard numerical methods.

5. CONCLUSIONS

The new development is the graphical method for calculating the Noise Exposure Index and the Equivalent Sound Level, based on measurements made during sampling periods.

The graphical method of evaluation can be applied in every situation and with every instrument, with no exceptions. The method is simple, fast, efficient with high accuracy, accessible to everyone, and can be applied to all conditions in Canadian mines and mills.

6. ACKNOWLEDGEMENTS

The author acknowledges the contribution of Dr. R. Tervo, Acting Manager, Elliot Lake Laboratory.

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5. Levens, A. S., "Graphical Methods in Research", John Wiley & Sons, Inc., New York, London, Sydney, 1965.
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APPENDIX 1

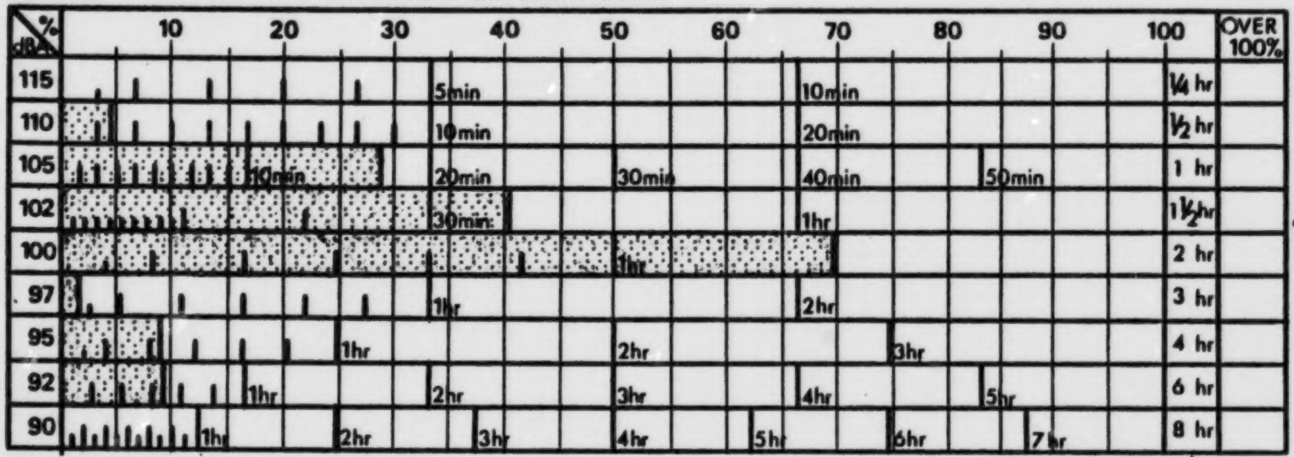
NOISE SUMVEY FORM

ELLIOT LAKE LABORATORY, CAN-MET, E.M.R.

SHEET: 2
DATE: 31-08-73

LOCATION: *MINES LTD., Underground crusher*

METHOD OF CALCULATING OSHA MIXED EXPOSURE INDEX



Σ TIME ▶ Hours 3 Minutes 15 ▲ OSHA

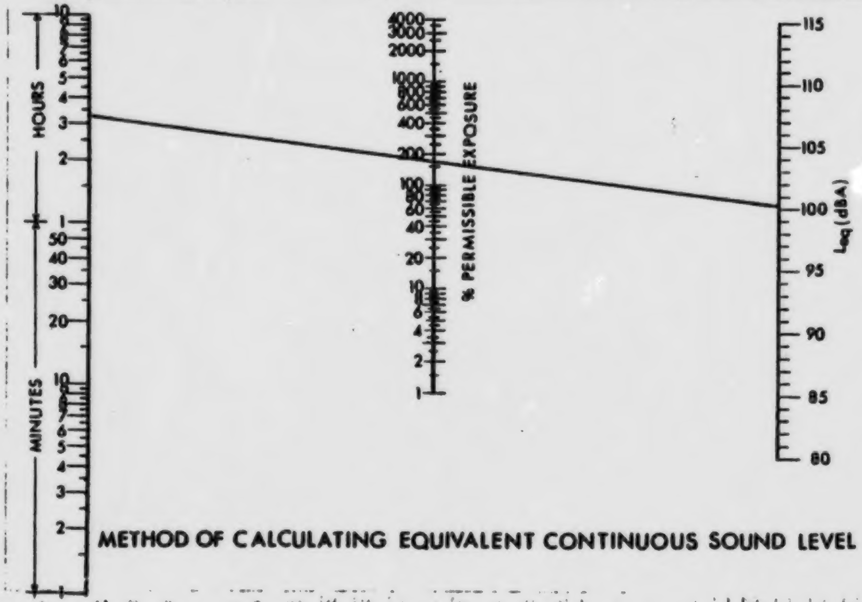
ADD EXPOSURE VALUES

165

% PERMISSIBLE EXPOSURE
DIVIDE BY 100
TO OBTAIN

1.65

OSHA
EXPOSURE INDEX



HOURS
MINUTES
% PERMISSIBLE EXPOSURE
Leq (dBA)
10
8
6
5
4
3
2
1
50
40
30
20
4000
3000
2000
1000
400
200
100
40
20
10
4
2
1
115
110
105
100
95
90
85
80

METHOD OF CALCULATING EQUIVALENT CONTINUOUS SOUND LEVEL

The equivalent continuous sound level → L_{eq} = 100.3 dBA

INSTRUMENT: *Sound Level Meter, Type 2205, B&K*

RECOMMENDATIONS: *Crusher operator should wear ear muffs.*

SIGNED: Mirony Savich

This [illegible] is supplied for preparing [illegible] for reproduction of paper or metal offset plates by "Xerox" or photographically. All material to be reproduced (typed, drawn or mounted) is to be kept within the blue boundary lines.

APPENDIX 2

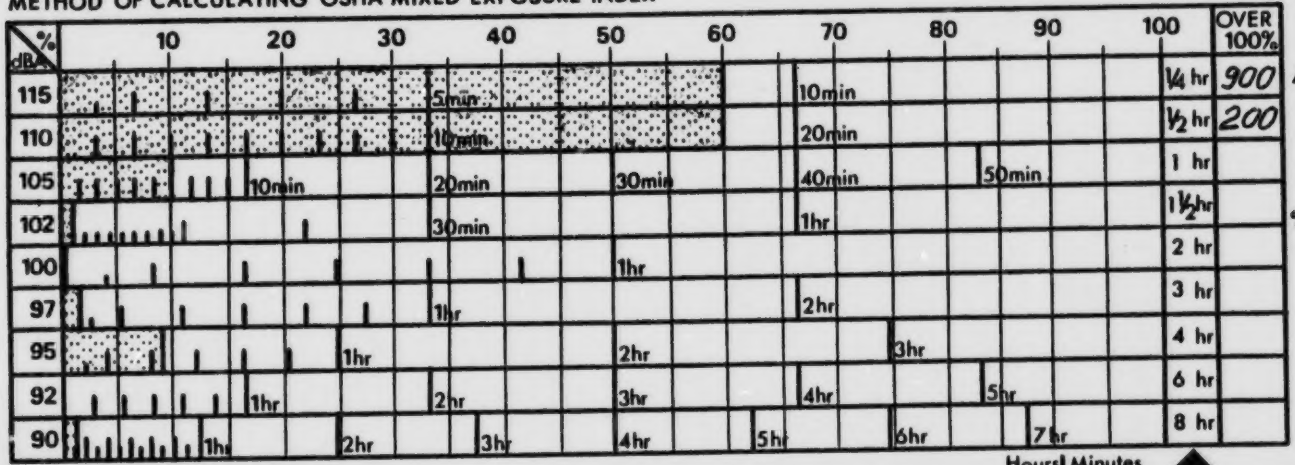
NOISE SURVEY FORM

ELLIOT LAKE LABORATORY, CAN-MET, E. M.R.

SHEET: 4
DATE: 21-08-74

LOCATION: COPPER MINES, Jumbo drill two (underground)

METHOD OF CALCULATING OSHA MIXED EXPOSURE INDEX



ADD EXPOSURE VALUES

1,243

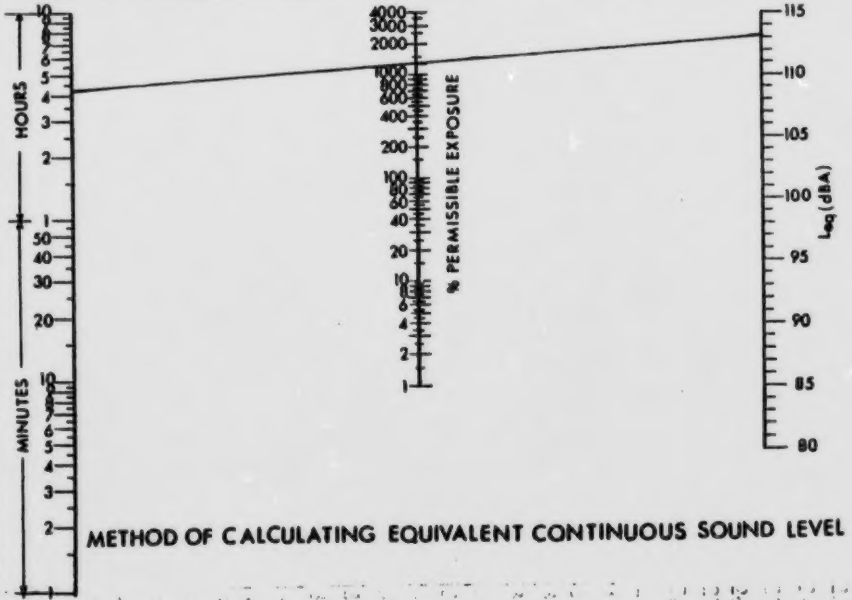
% PERMISSIBLE EXPOSURE DIVIDE BY 100 TO OBTAIN

12.43

OSHA EXPOSURE INDEX

	Hours	Minutes
Σ TIME ▶	4	13

▲ OSHA



METHOD OF CALCULATING EQUIVALENT CONTINUOUS SOUND LEVEL

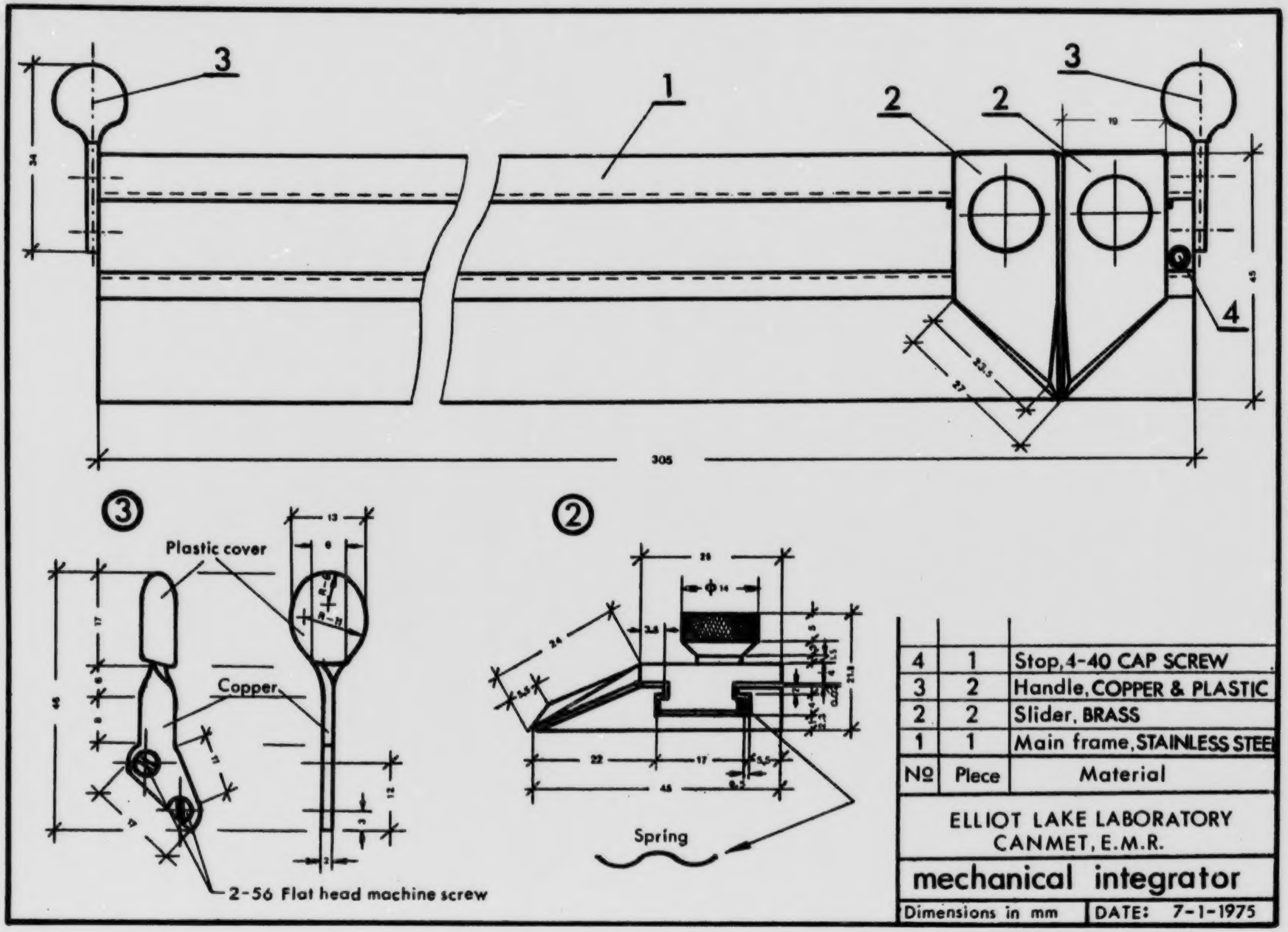
The equivalent continuous sound level → Leq = 113.2 dBA

INSTRUMENT: Sound Level Meter, Type 2205, B&K

RECOMMENDATIONS: Jumbo drill operator should wear ear plugs and ear muffs.

SIGNED: Chirony Srich

APPENDIX 3


3
1
2
2
3
4
10
34
45
23.5
27
305
③
Plastic cover
Copper
2-56 Flat head machine screw
13
8
17
45
11
12
3
2
②
28
Φ14
3.5
24
5.5
22
17
45
5.5
21.4
Spring

Nº	Piece	Material
4	1	Stop, 4-40 CAP SCREW
3	2	Handle, COPPER & PLASTIC
2	2	Slider, BRASS
1	1	Main frame, STAINLESS STEE

ELLIOT LAKE LABORATORY
CANMET, E.M.R.

mechanical integrator

Dimensions in mm
DATE: 7-1-1975

Page 207

VoL. 1 Report 7

75-71 M. Savich

Simple method of evaluation of the noise exposure index and the equivalent continuous sound level

1975

Caractéristiques du dosimètre de bruit GR-1944 au laboratoire et sur le terrain

par

Miron Savich*

RÉSUMÉ

Nous avons évalué le dosimètre de bruit GR-1944, disponible dans le commerce. Les méthodes d'évaluation et de calcul de l'indice d'exposition au bruit au laboratoire et sur un lieu de travail réverbérant sont présentées. Ces essais nous permettent de conclure, une fois tous les facteurs envisagés, que l'appareil de surveillance du bruit GR-1944 peut être adapté à un casque de mineur pour la mesure de l'indice d'exposition au bruit dans les mines. L'appareil satisfait les critères de réponse en fréquence pondérée A fixés par la norme ANSI SI.4-71 pour les sonomètres de type 2.

Mots-clés : Bruit, exposition, dosimètre, GENRAD, précision

* Chercheur, Laboratoire d'Elliot Lake, Laboratoires de recherche minière, Centre canadien de la technologie des minéraux et de l'énergie, ministère de l'Énergie, des Mines et des Ressources, Elliot Lake (Ontario).

Characteristics of GR-1944 Noise Dosimeter in the Laboratory and in the Field

by

Miron Savich*

ABSTRACT

Testing was done on a commercially available GR-1944 Noise Dosimeter. Methods for testing and calculating the Noise Exposure Index in a laboratory and in a reverberant work area are presented. On the basis of tests, if all factors are considered, the GR-1944 Noise Monitor can be adapted to a miner's hat for measuring Noise Exposure Index in mines. The unit met A - weighting frequency response tolerance for ANSI S1.4-71 Type 2 Sound Level Meter.

Keywords: Noise, Exposure, Dosimeter, GENRAD, Accuracy

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1. INTRODUCTION

Tests in the Elliot Lake Laboratory were conducted on the GENRAD (General Radio) Type 1944 Noise Dosimeter including Type 1944-9701 Noise Exposure Monitor and Type 1944-9702 Noise Exposure Indicator, to be adapted in the Noise Monitor Hat, to investigate occupational noise exposure index (EI) in underground environmental conditions (1 and 2). In a study for testing the performance of the Noise Dosimeter, a precision sound level meter, B and K, Type 2209, ANSI* S1.4-71, and level recorder, B and K, Type 2306 were used to standardize the noise levels and to answer the following questions:

1. What accuracy can be expected from a GENRAD Noise Dosimeter in laboratory conditions?
2. What accuracy can be expected in the mining environment?

The Noise Dosimeter meets new OSHA requirements and procedures to limit occupational noise exposure (U.S. Public Law 91-596).

---

* American National Standards Institute

Table 1
OSHA Permissible Exposure Limit,
Steady State Noise-Single Level
(Public Law 91-596)

Sound Level (dBA)	Time Permitted (Hours)	Sound Level (dBA)	Time Permitted (Hours)
85	16.0	101	1.733
86	13.933	102	1.517
87	12.133	103	1.317
88	10.55	104	1.15
89	9.183	105	1.0
90	8.00	106	0.867
91	6.967	107	0.75
92	6.067	108	0.667
93	5.283	109	0.567
94	4.6	110	0.5
95	4.0	111	0.433
96	3.483	112	0.383
97	3.033	113	0.333
98	2.633	114	0.283
99	2.3	115	0.25
100	2.0	> 115	None

The criteria are based on measurements of the equivalent continuous noise level, Leq, provided the noise is not of an "impulsive" nature. Limits are based on tests showing that, for every halving of the duration of exposure, the intensity of exposure can be increased 5 dBA without an increase in the risk of noise-induced hearing losses. The A-weighted reading is used to estimate the probability of hearing damage in industry.

2. NOISE DOSIMETER

Sound Level meters can be used to accurately measure the noise level at a given point at the time of the observation. They are not designed to electronically sum up the noise exposures of active employees. This problem is minimized by use of the noise dosimeter.

The GENRAD 1944 Noise Dosimeter has two parts:

- 1944 - 9701 Noise Exposure Monitor, and
- 1944 - 9702 Noise Exposure Indicator.

The 1944 - 9701 Noise Exposure Monitor has two versions:

(1) Monitor with remote microphone, and

(2) Monitor with built-in microphone.

The microphone should be placed on the ear or on the shirt collar sliding one of the clips up to the microphone. The clip can be attached to the collar, high on the shoulder, with the microphone facing to the side or up. Thus, sound from the front, and one side are weighted approximately equally in the measurement.

The 1944-9701 Noise Exposure Monitor, including a built-in microphone, is worn in the employee's shirt pocket. The windscreen protects the microphone from dust, reduces the effect of wind - generated noise, and is necessary during the calibration for a good seal around the microphone.

All sound levels between 85 and 115 dBA are accumulated continuously in a semiconductor memory circuit; alsothe fact of whether the 115 dBA limit has been exceeded (1). The indicator reads from 1% to 999% on light-emitting display in 1% steps. Crest-factor capacity at full scale (115 dBA) is greater than 15 dB.

The 1944-9702 Noise Exposure Indicator is used to obtain a reading of the noise exposure level experienced by the worker wearing the dosimeter and to calibrate the individual monitor units. When the monitor is inserted into the socket of the readout device, the worker's daily noise exposure is displayed as a percentage of the allowable limit. A light shows when 115 dBA has been exceeded (stored in Monitor Unit). The monitor can be reset after the exposure information is read from the readout device, or it can be returned to the worker for further accumulation. The final readout is the sum of all the exposure ratios that were measured and calculated by the monitor during the work period. The 1944 - 9702 Noise Dosimeter meets the accuracy requirements specified by the American National Standard Institute for general purpose sound level meters (S1.4-1971, Type 2), is capable of handling the integration specifications of OSHA, and is also capable of acoustical calibration in the field.

3. PERFORMANCE DATA FOR THE NOISE DOSIMETER

Tests were carried out in three places:

(1) Noranda Research Centre; laboratory tests were in 2 semi-reverberant rooms ~ 20 m long, 5 wide and 4.5 m high. The room was full of machines. Acoustical tests were performed using sine random generator, Band K, type 1027, power amplifier, B and K, type 2706, and loudspeaker.

(2) Elliot Lake Laboratory; laboratory tests were in a semi-reverberant room 8.2 m long, 7.9 m wide and 4.6 m high. The room also was full of machines. Acoustical tests were performed using a Hewlett-Packard test oscillator, model 650A. The high-powered loudspeaker was oriented to eliminate directional effects and to achieve a diffuse noise condition.

(3) In mines; tests were performed in a reverberant power house 39 m long 16.5 m,wide and 10 m high. In the power house eight compressors, two vacuum pumps, and two blowers were operated.

3.1 The Accuracy of the Noise Dosimeters

The accuracy of personal noise monitoring, whether using an audio dosimeter or sound level meter, is a function of the total tolerance limits for sound at random incidence for a Type 2 Sound Level Meter. The effect of dBA measurement variation on percentage reading was derived from the standard for General Purpose Sound Level Meters S1.4-1971, Type 2, and OSHA compliance (Table 2).

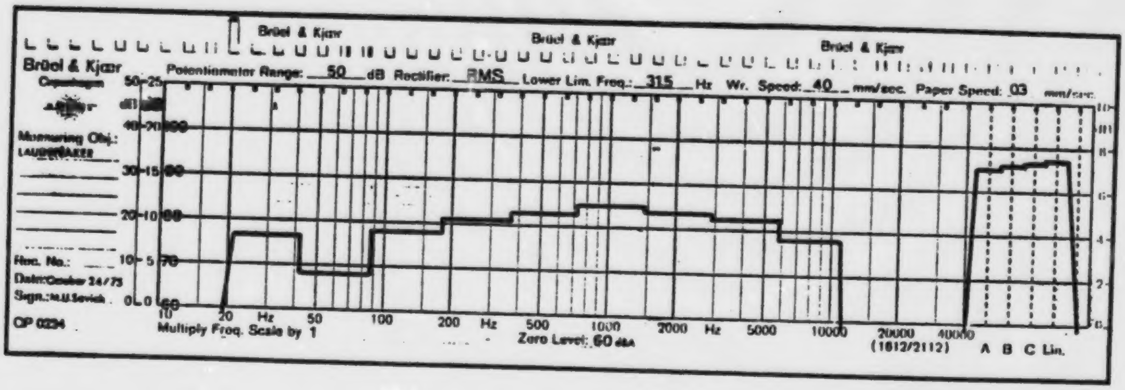
Table 2
The Effect of dB Error on Percent
OSHA Exposure Measurement

Error dB	Percent Reading when Expecting 100%	Error dB	Percent Reading when Expecting 100%
+6.0	230	-1.0	87
+5.0	200	-2.0	76
+4.0	187	-3.0	66
+3.0	152	-4.0	57
+2.0	132	-5.0	50
+1.0	115	-6.0	43
0	100		

A calculation of the effect instrumental tolerance limits was done using "pink noise" from 20 Hz to 10,000 Hz for the input signal spectrum for the A response and again for the upper and lower limits for type 2 tolerance. The measured dBA value may deviate in the range of +3.4 dBA to -2.1 dBA from the correct noise level (3). Any result between 76% and 160% will be acceptable.

3.2 Comparison of Effects of dBA Variation on Percentage Reading between Two New Noise Dosimeters

A comparison was made of the values of the Noise Exposure Index measured by two GR-1944 Noise Dosimeters. The Noise Exposure Monitors were previously calibrated. During the calibration and reading of the results only one GR-1944 Noise Exposure Indicator was used to eliminate errors due to any discrepancy between indicators. Pink Noise output wave forms, from a sine random generator, B and K, Type 1027, were used for response measurements (Figure 1). Noise whose spectrum level decreases with increasing frequency to yield constant energy per octave of bandwidth



Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 315 Hz Wr. Speed: 40 mm/sec. Paper Speed: 03 mm/sec.

Measuring Obj.: LAUDSPEAKER

Rec. No.:

Date: October 24/73

Sign.: M.U.Sevick

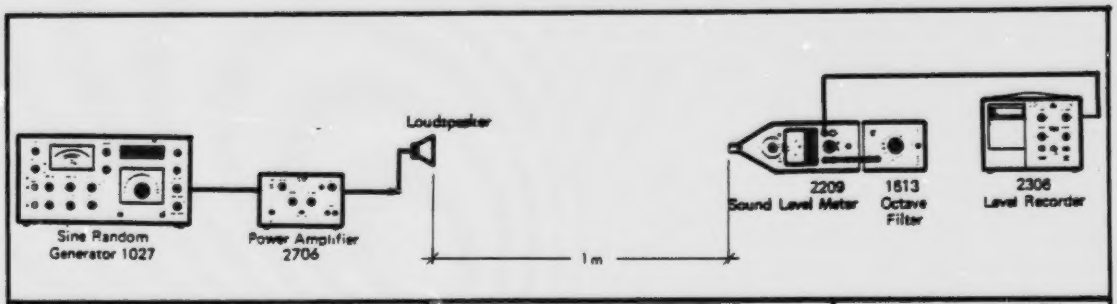
Zero Level: 60 dBA

Figure 1: Octave Frequency Analysis of the Sine Random Generator, Band K, Type 1027, Pink Noise Output

is called Pink Noise.

Test results and procedures are shown in Table 3. Monitor microphones were attached to the microphone of the sound level meter, B and K, type 2209. From the results it is evident that the borrowed noise dosimeter from GENRAD gave the result of zero at noise level 85 dBA.

Table 3
Comparison of Permissible Exposure Value in Percent between Two New GR-1044 Noise Dosimeters


Sine Random Generator 1027
Power Amplifier 2706
Loudspeaker
1 m
2209 Sound Level Meter
1613 Octave Filter
2306 Level Recorder

No.	LEVEL (dBA)	TIME (min.)	PERMISSIBLE EXPOSURE VALUES IN PERCENT			PERCENT READING WHEN EXPECTING 100%	
			EXPECTING	NOISE DOSIMETER GR-1944		NOISE DOSIMETER GR-1944	
				CANMET	GENRAD	CANMET	GENRAD
1	85	24	2.5	3	0	120	0
2	88	12	2	2	2	100	100
3	89	12	2.2	2	3	91	136
4	90	12	2.5	3	4	120	160
5	90	12	2.5	3	3	120	120
6	95	12	5	6	7	120	140
7	105	12	20	24	30	120	150

3.3 Test Data for Dynamic Range

The test for dynamic range shows extremly good results. An inhibition at 85 dBA is good, and all results are close (Figure 2). The Noise Exposure Indicator counts over 115 dBA. All readings were within tolerance.

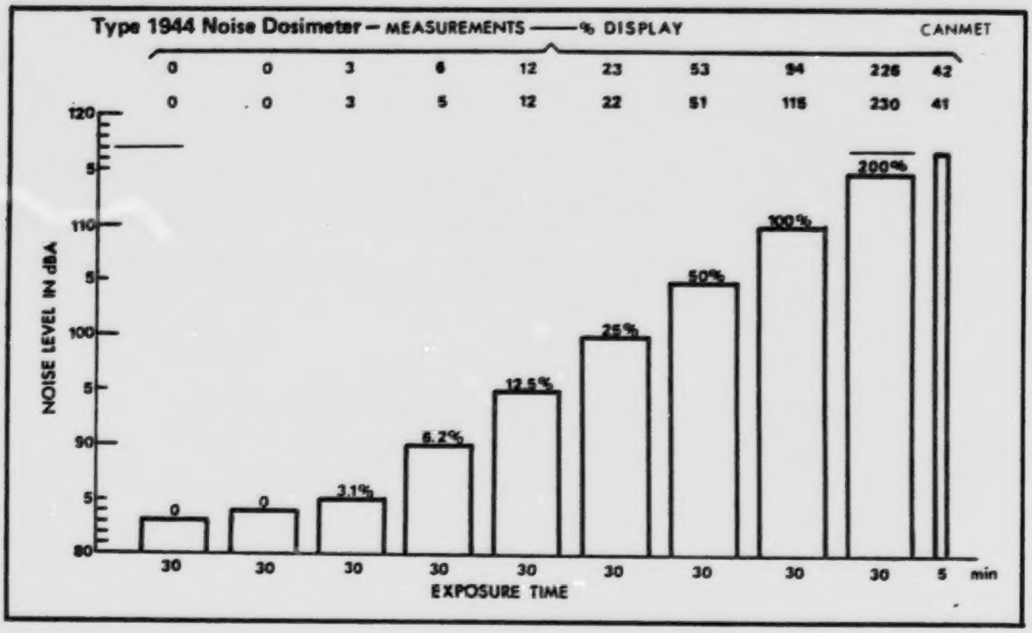


Figure 2: Test Level for Dynamic
Range at 1kHz.

3.4 Accumulative Test for 100% Total

This test was carried out to evaluate the ability of the GR-1944 Noise Dosimeter to accumulate noise signals of various fixed levels and durations (Figure 3). The sound level was controlled in each interval to correspond to 16.6 percent exposure. All readings were within tolerance.

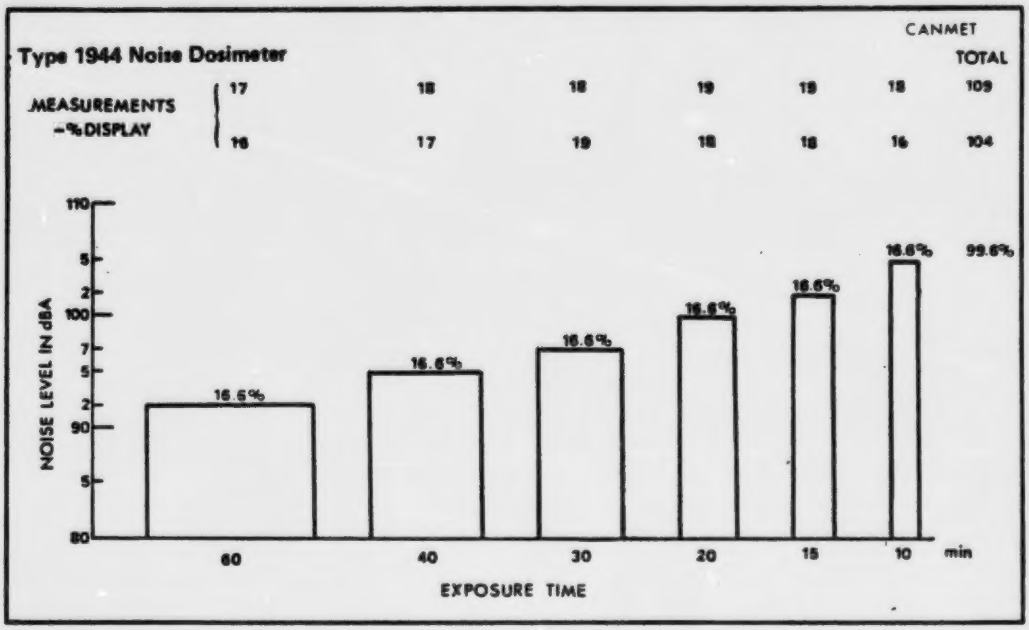


Figure 3: Accumulative Test for
100% Total at 1kHz.

3.5 Exposure Test to Octave Bands of Noise

The Noise Monitor was exposed to octave bands of noise at 100 dBA for one hour from 125 Hz to 4,000 Hz (Figure 4). Each exposure corresponds to a 50% exposure according to the OSHA criterion. Examination of the test data showed the 4,000 Hz band to have the greatest error.

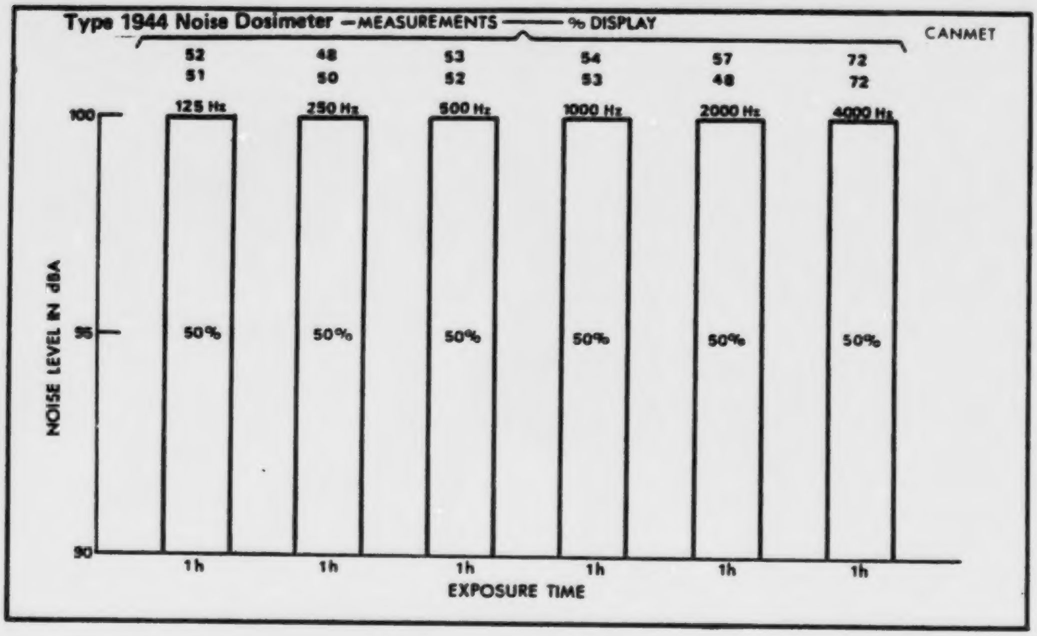


Figure 4: One-Hour Exposure to
Octave Bands of Noise.

3.6 Noise Burst Test

The noise burst test was performed to investigate the effects of intermittent noise peaks (Figure 5). The background level was less than 85 dBA with 115 dBA pulses of 2 seconds duration separated by intervals of ten seconds; 30 minutes produces 33.4% exposure. OSHA has established the A-scale at slow response characteristic of a sound level meter as the criterion for measuring noise levels. It was believed that results obtained with the Noise Monitor from short duration noise pulses might be lower than calculated values of time versus intensity. The test was repeated three times and showed the high quality of the instrument.

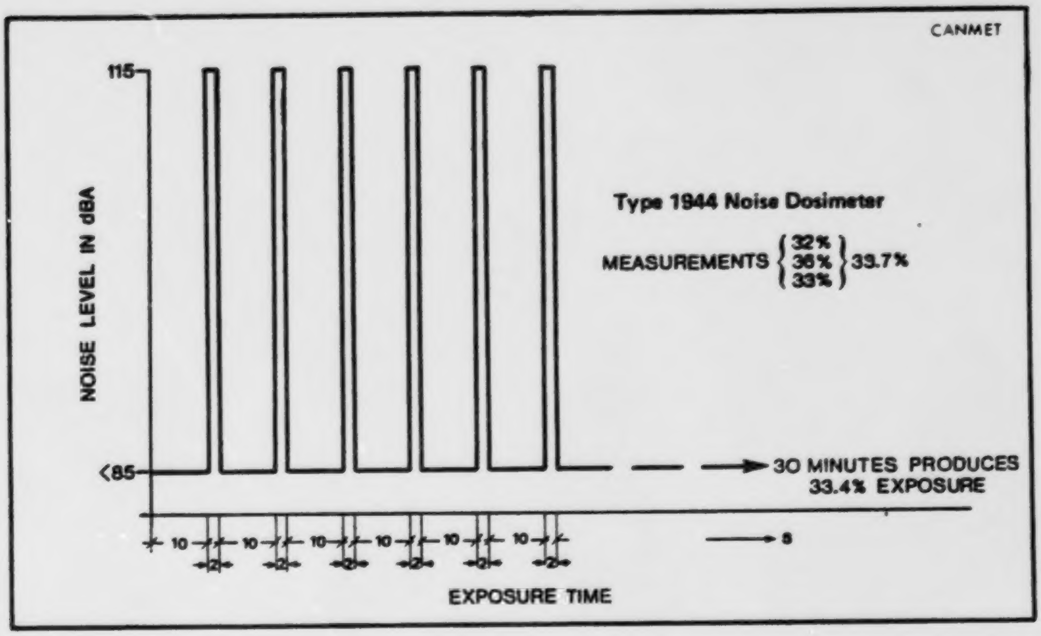


Figure 5: Noise Burst Test with <85 dBA Background at 1kHz.

Sound level meter, B and K, Type 2209, and level recorder, B and K, Type 2306 were connected for measuring and analyzing these signals. The recorder is not able to record the 115 dBA peaks accurately at the slowest and fastest writing speed (Figure 6). We must take this into account during future field measurements. The recorded rms value from the level recorder, Type 2306 is accurate within ± 0. 5 dB for signals with crest factors up to 3 (4).

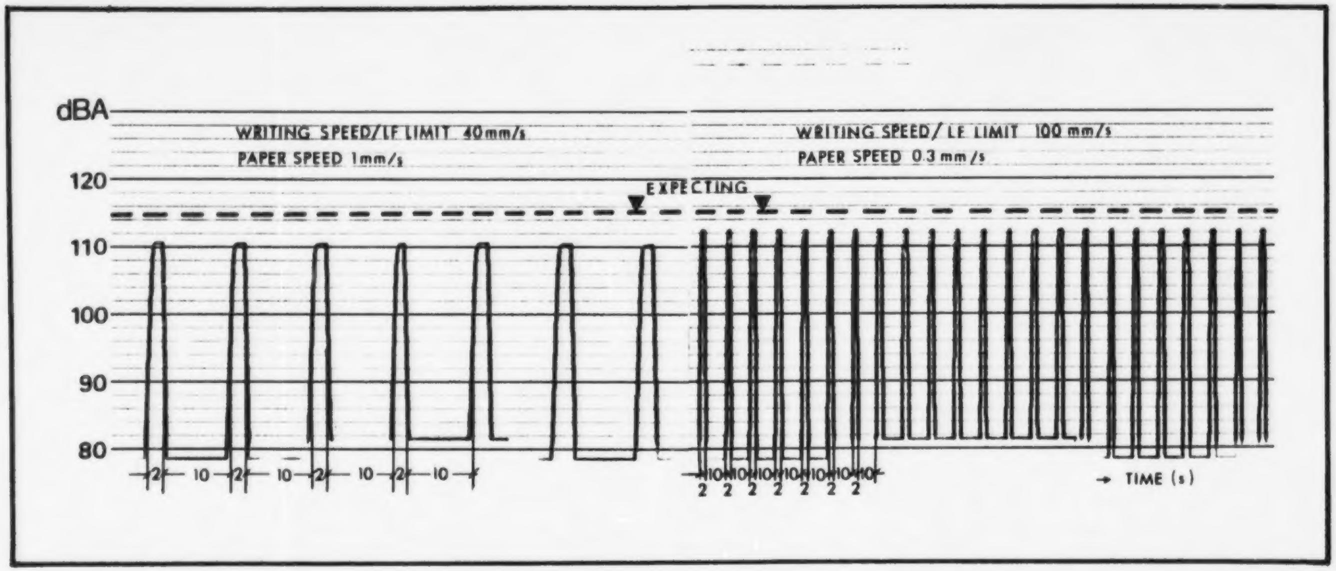


Figure 6: Noise Burst Measurements Observed by
Level Recorder, B and K, Type 2306
at different Writing and Paper Speed

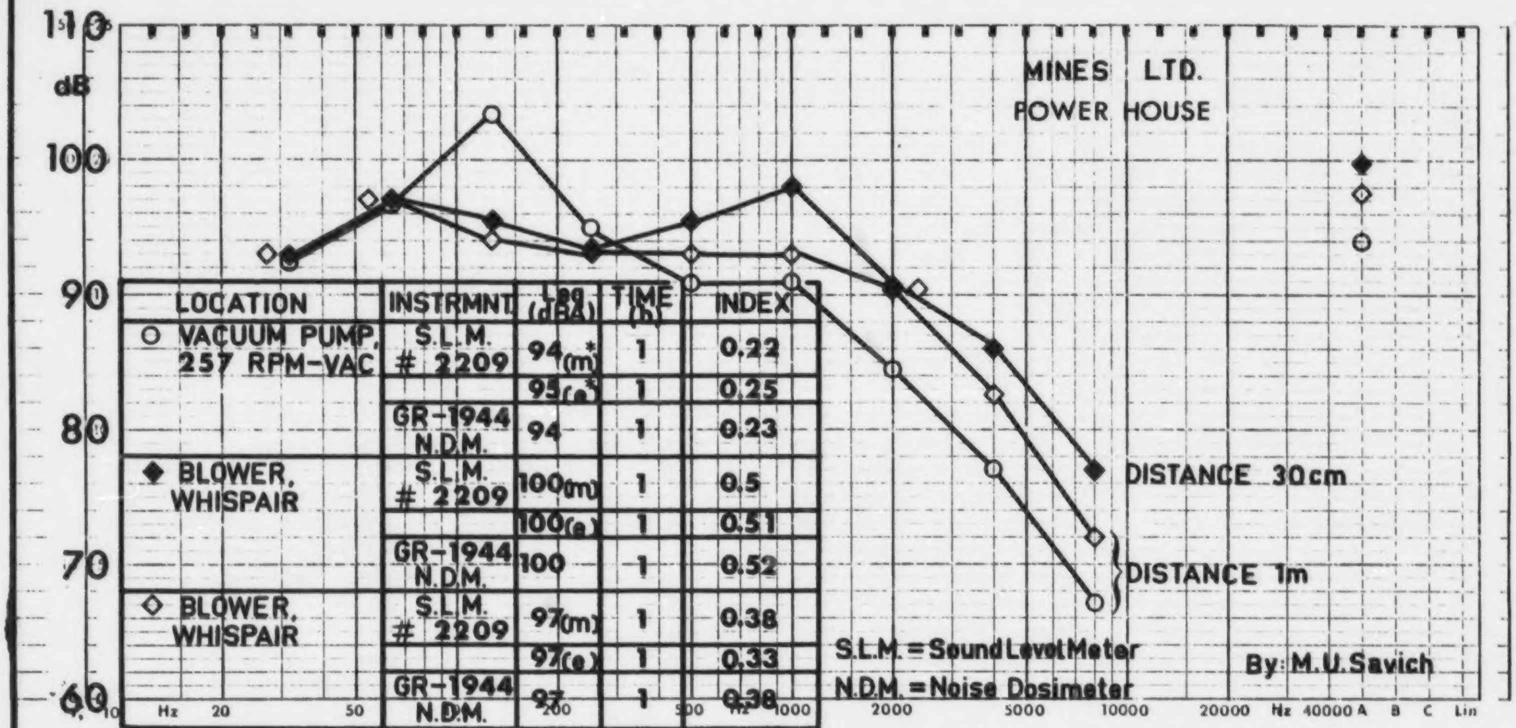
3.7 Measurements in a Reverberant Work Area

In this test the accuracy of the Noise Dosimeter was observed and in addition, the Dosimeter readings were compared to readings taken with sound level meter, B and K, type 2209, octave filter, B and K, type 1613, and level recorder, B and K, type 2306. In Figure 7, test results indicate close agreement among the GR-1944 Noise Dosimeter with the data of the wide strip chart recording paper of Level Recorder. This is believed to be related to the reverberant characteristics of the power house. Although the noise varied in intensity, reverberation provided some uniformity to the distribution of the variations. Under these conditions microphone placement on the worker would not appear to be critical.

In the second test the effects of microphone placement were observed, the Dosimeter readings were compared to readings taken with the sound level meter in the center of the power house. The worker was involved for 1 hour of normal work in the power house. The microphone's placement was over the ear.

In Table 4, test results show very close agreement between the Noise Dosimeter and sound level meter reading at an altitude of 1.8 m.

The disagreement at altitude 1.5 m can be attributed to the absence of reflective surfaces in the work area where measurements were obtained.



LOCATION	INSTRMNT	Leq (dBA)	TIME (h)	INDEX
○ VACUUM PUMP, 257 RPM-VAC	S.L.M. # 2209	94 (m)*	1	0.22
		95 (e)*	1	0.25
	GR-1944 N.D.M.	94	1	0.23
◆ BLOWER, WHISPAIR	S.L.M. # 2209	100 (m)	1	0.5
		100 (e)	1	0.51
	GR-1944 N.D.M.	100	1	0.52
◇ BLOWER, WHISPAIR	S.L.M. # 2209	97 (m)	1	0.38
		97 (e)	1	0.33
	GR-1944 N.D.M.	97	1	0.38

* MEASURED (m); ESTIMATED (e) Total noise estimated from the octave-band noise levels given in the noise spectrum. Approximate agreement with measured total noise indicates reasonably constant conditions during period of measurement.

Figure 7: Spectral Analysis of Vacuum Pump and Blower, Whispair, with Lower Frequencies Dominant

Table 4
Measurements of Noise Exposure Index in a Reverberant Work Area in Power House at Mines Ltd.

Microphone placement	Leq (dBA)	Time (h)	Index
S. L. M. #2209 Altitude from floor 1.5 m	92	1	0.165
S. L. M. #2209 Altitude from floor 1.8 m	93	1	0.19
GR - 1944 N. D. M. Over ear	94	1	0.22

Also, in the center of the power house, lower frequencies are predominant.

Hz	31	63	125	250	500	1K	2K	4K	8K
dBA	93.5	98	96.5	89.5	89	88.5	84	76	66

dBA	dBB	dBC	Lin
92	97	101	102.5

Estimated[+]: 92.35 dBA

[+] Total noise estimated from the octave-band noise level. Approximate agreement with measured total noise indicates reasonably constant conditions during period of measurement.

The short sample of the noise emitted by the machines can be extrapolated to longer times if machine operation is steady. In this case from Table 4, Leq = 94 dBA, and in accordance with OSHA criteria the noise-exposure index corresponding to 8-hour of exposure is 1.74.

4. CONCLUSIONS

1. - Testing was done on a commercially available GR-1944 Noise Dosimeter. The unit met A-weighting frequency response tolerance for ANSI S1. 4-71 type 2 Sound Level Meters.

2. - For sound level range the factory claims: "85 to 115 dBA (re 20 μ N/m^2) Crest-factor capacity at full scale (115 bDA) is greater than 15 dB". In our tests the Noise Dosimeter counts over 115 dBA (Figure 2).

3. - The Noise Exposure Monitor is not made for underground purposes as the electronics and packaging of the instrument are not suitable for mine environment, but when adapted to the hat, can be very rugged.

4. - Fixed position sound level meters or stationary noise monitors do not appear to be as valuable as personal noise exposure monitors or noise dosimeters to obtain data for Noise Exposure Index.

5. - A new generation of GENRAD dosimeters will be on the market in a short time. GR-1954 Noise Dosimeters are smaller than GR-1944.Indicator looks similar, but is thinner, The microphone can be used in two ways: remote or built-in.

5. ACKNOWLEDGEMENTS

K.G. Wheeland, Head, Department of Process Technology, Noranda Research Centre, Montreal, participated in the development of the project. Geoff Perry, President, Bruel and Kjaer Canada Ltd., Montreal, provided the sine random generator, power amplifier and loudspeaker for testing at

Noranda Research Centre. The author acknowledges the contribution of R. Tervo Acting Manager, Elliot Lake Laboratory, and of H. Montone who provided technical assistance.

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Characteristics of GR-1944 noise dosimeter in the laboratory and in the field

1976

MÉTHODE GRAPHIQUE SIMPLE D'ÉVALUATION DE L'INDICE D'EXPOSITION AU BRUIT ET DU NIVEAU SONORE CONTINU ÉQUIVALENT

par

M. Savich*

RÉSUMÉ

Une méthode graphique a été mise au point pour l'évaluation de l'indice d'exposition au bruit, selon les critères de l'Occupational Safety and Health Act (États-Unis), et du niveau sonore continu équivalent. Dans cette méthode, on utilise une formule de relevé du bruit et un intégrateur mécanique comportant deux coulisses. La méthode est moins fastidieuse et plus sûre que d'autres méthodes.

La méthode graphique peut être adpatée à divers codes utilisés pour le calcul de l'exposition au bruit et elle peut être employée avec n'importe quel instrument qui mesure le niveau de bruit. Un exemple de son application dans une mine canadienne est donné à des fins d'illustration.

Indice d'exposition au bruit, niveau sonore continu équivalent, évaluation, formule de relevé du bruit, intégrateur mécanique.

* Chercheur, Laboratoire d'Elliot Lake, Laboratoires de recherche minière, Centre canadien de la technologie des minéraux et de l'énergie, ministère de l'Énergie, des Mines et des Ressources, Elliot Lake (Ontario).

SIMPLE GRAPHICAL METHOD OF EVALUATION OF THE NOISE EXPOSURE INDEX AND THE EQUIVALENT CONTINUOUS SOUND LEVEL

by

M. Savich*

ABSTRACT

A graphical method has been developed for the evaluation of the U.S. Occupational Safety and Health Act Noise Exposure Index and the Equivalent Continuous Sound Level. The method makes use of a Noise Survey Form and a Mechanical Integrator with two sliders, and is less tedious and susceptible to error than alternative methods.

The graphical method is adaptable to various codes for noise exposure and may be used with any instrument that measures noise level. One example of its application to a practical situation in a Canadian mine is given to demonstrate the procedure.

Noise Exposure Index, Equivalent Continuous Sound Level, Evaluation, Noise Survey Form, Mechanical Integrator.

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1. INTRODUCTION

After a few years of experience with the application of standards contained in noise regulations and codes, more and more mining engineers are becoming involved in the problems associated with them, the way they are implemented and the high cost of compliance (1).

In the application of noise regulations and codes they must measure certain noise functions, one of which is the Noise Exposure Index (NEI) or Noise Dose. NEI is the integrated noise exposure expressed as a percentage of the maximum permissible exposure. Although instruments are available for measuring NEI directly it is sometimes necessary or desirable to evaluate it from measurements made with a simple sound level meter.

Such an evaluation requires extensive calculations, which are extremely tedious if performed numerically. A simple graphical method is proposed for calculating NEI, that is much less tedious than alternative methods. It is also flexible; it can be adapted to tests of the applicability of a new or modified code.

2. DEFINITIONS OF NOISE EXPOSURE INDEX AND EQUIVALENT CONTINUOUS SOUND LEVEL

2.1. Noise Exposure Index (NEI)

The noise exposures permitted by OSHA* regulation are given in Table 1.

When the noise consists of different dBA noise levels throughout the day, the combined exposure is controlled by calculating:

---

* The Occupational Safety and Health Act (U.S.A.).

$$\Sigma C/T = (C_A/8 + C_B/6 + C_C/4 + C_D/3 + C_E/2 + .. + C_J/0.25) \qquad \text{(Eq 1)}$$

where C_A is the total time the noise level is in band A, C_B is the total time the noise level is in band B, etc., and requiring that $100\ \Sigma C/T$ = NEI, the OSHA Mixed Exposure Index, must be $\leq$ 100%. This requirement is based on tests showing that, for every halving of the duration of exposure, the intensity of exposure can be increased 5 dBA without an increase in the risk of noise-induced hearing losses.

TABLE 1

Noise Exposure Limits for a Normal 8-Hour Working Day

Band	Noise Level (dBA)	Maximum Exposure (h)
A	90	8
B	92	6
C	95	4
D	97	3
E	100	2
F	102	1. 5
G	105	1
H	110	0. 5
J	115	0. 25
	Above 115	None

2. 2. Equivalent Continuous Sound Level (L_{eq})

L_{eq} is defined mathematically by (2):

$$L_{eq} = \frac{q}{\log_{10} 2} \log_{10}\left[\frac{1}{T}\int_0^T \left(\frac{p(t)}{p_o}\right)^{\frac{20 \log_{10} 2}{q}} dt\right] \qquad \text{(Eq 2)}$$

where: q is 5 (5 dBA increase for halving of duration, OSHA).

T is the total sampling period in hours,

$p(t)$ is the instantaneous A-weighted sound pressure in Pa (pascal),

p_o is the reference r.m.s. sound pressure, 2×10^{-5} Pa, and

t is the time in hours.

When the sound level is constant, L_{eq} is equal to the reading of a sound level meter. When the sound level is not constant, direct indication of L_{eq} requires a specialized instrument.

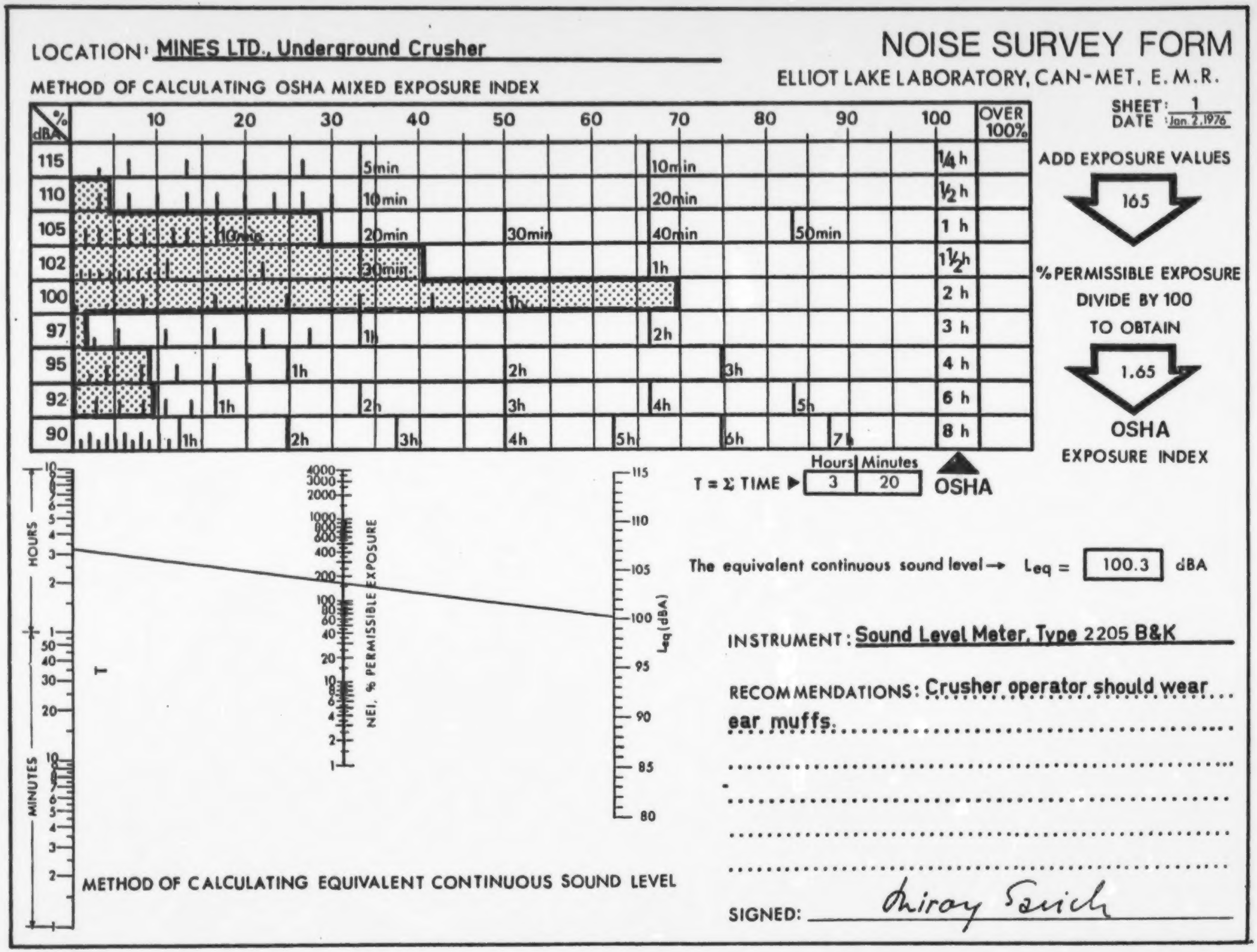
3. INSTRUMENTS FOR NOISE MEASUREMENT

The basic instruments for noise measurement and for measuring noise exposure are (3):

1. Sound level meter, a stopwatch and a data sheet for full-shift information;
2. Graphical level recorder to provide a continuous record of the r.m.s. sound pressure level versus time, for full-shift information;
3. Statistical analyzer to provide data for a manual analysis based on partial shift information;
4. Noise dosimeter to automatically integrate the sound energy received with regard to level and time;
5. Profiling dosimeter to automatically integrate the amplitude distribution histograms, computations of exposure index, L_{eq} and time (new instruments).

4. PROCEDURES FOR CALCULATING NOISE EXPOSURE INDEX AND EQUIVALENT CONTINUOUS SOUND LEVEL

For fast and simple evaluation of the Noise Exposure Index a Noise Survey Form is made (Fig. 1) and the Mechanical Integrator with two sliders (Fig. 2) is used. Instead of the Mechanical Integrator, an ordinary ruler or piece of paper can be used.



NOISE SURVEY FORM

ELLIOT LAKE LABORATORY, CAN-MET, E. M. R.

LOCATION: MINES LTD., Underground Crusher

SHEET: 1
DATE: Jan. 2, 1976

METHOD OF CALCULATING OSHA MIXED EXPOSURE INDEX

ADD EXPOSURE VALUES 165

% PERMISSIBLE EXPOSURE DIVIDE BY 100 TO OBTAIN 1.65 OSHA EXPOSURE INDEX

T = Σ TIME ▶ Hours 3 Minutes 20

The equivalent continuous sound level → L_{eq} = 100.3 dBA

INSTRUMENT: Sound Level Meter, Type 2205 B&K

RECOMMENDATIONS: Crusher operator should wear ear muffs.

SIGNED:

METHOD OF CALCULATING EQUIVALENT CONTINUOUS SOUND LEVEL

% / dBA
10 20 30 40 50 60 70 80 90 100
OVER 100%
115 110 105 102 100 97 95 92 90
5min 10min ¼ h
10min 20min ½ h
10min 20min 30min 40min 50min 1 h
30min 1h 1½ h
1h 2 h
1h 2h 3 h
1h 2h 3h 4 h
1h 2h 3h 4h 5h 6 h
1h 2h 3h 4h 5h 6h 7h 8 h
OSHA
HOURS
MINUTES
T
NEI, % PERMISSIBLE EXPOSURE
L_{eq} (dBA)
115 110 105 100 95 90 85 80

Fig. 1: Noise Survey Form

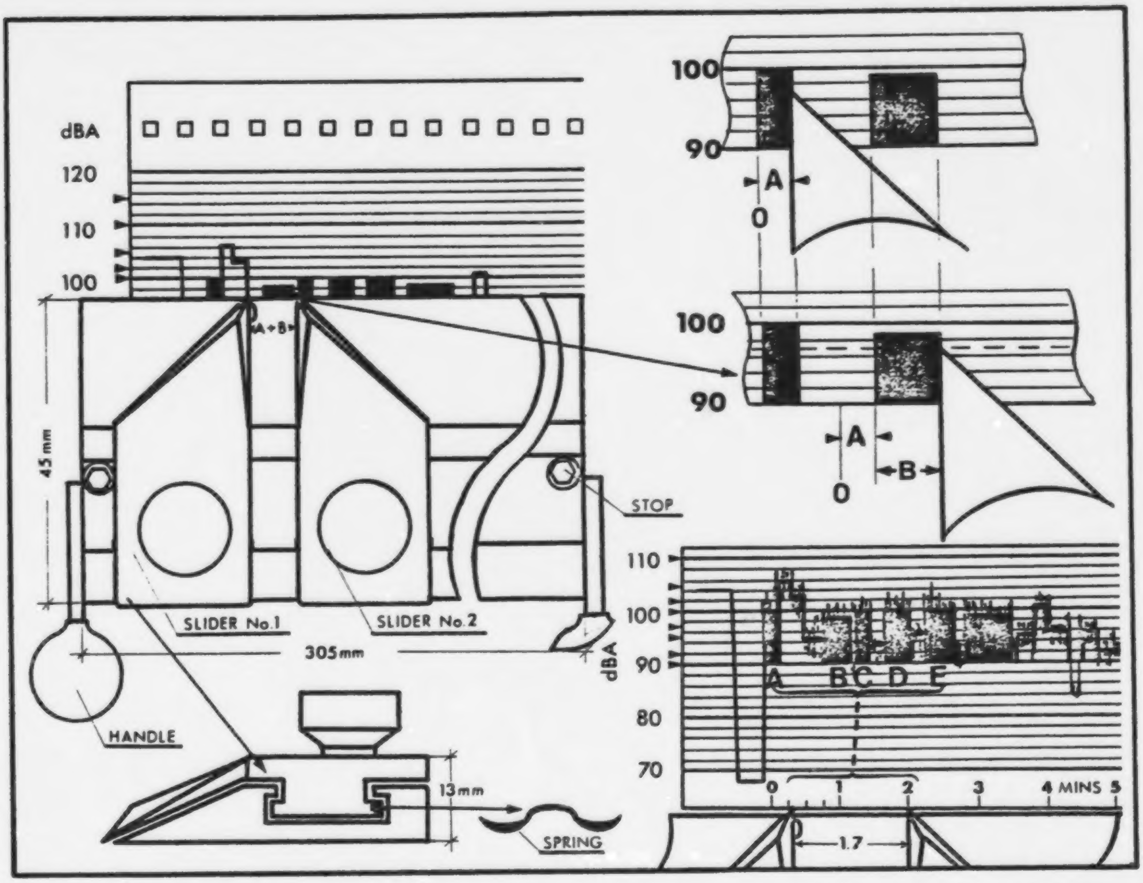

dBA
120
110
100
A+B
45mm
SLIDER No.1
SLIDER No.2
305mm
HANDLE
13mm
SPRING
STOP
100
90
A
0
100
90
A
B
0
110
100
90
80
70
dBA
A B C D E
0 1 2 3 4 MINS 5
1.7

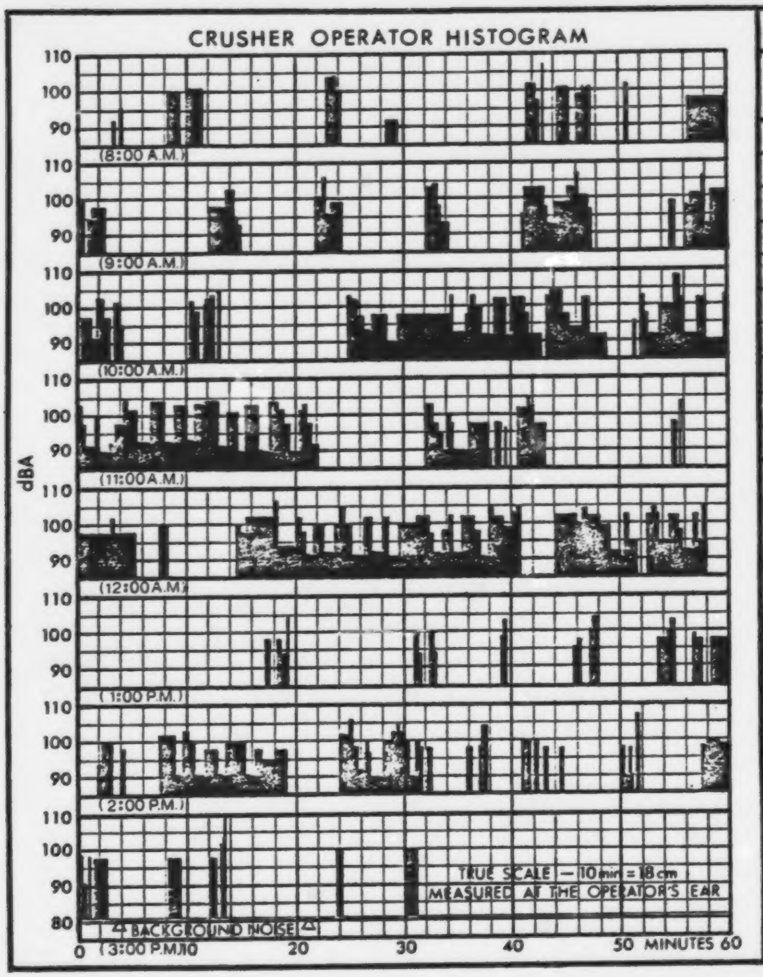
Fig. 2: Using the Mechanical Integrator to determine the Exposure Time from a Graphic Level Recorder Output.

(1) Choose a level (here 100 dBA). Place "O" of rule (Slider No. 1) at first point, move Slider No. 2 to second point, as shown.
(2) Move entire rule, to the right, until left edge of Slider No. 2 rests on the next point, etc.

4. 1. Estimation of Exposure Times

The evaluation of the total exposure time at various noise levels is done as follows:

1. The average levels on paper tape are estimated and marked with a pencil to obtain an operator histogram (Figs. 2 and 3).
2. The base line is determined by the standard or act (here 90 dBA).
3. The lines of permissible noise levels according to the standard or act



OSHA

dBA NOISE LEVEL	C*	T✡	$\frac{C}{T}$
>115	–	–	–
115	–	¼	–
110	0.028	½	0.056
105	0.307	1	0.307
102	0.611	1½	0.407
100	1.361	2	0.681
97	0.061	3	0.020
95	0.340	4	0.085
92	0.582	6	0.097
90	0.018	8	0.002
			1.655

Δ NEI

Note:
* Total duration in hours per day.
✡ Permissible hours per day.

$L_{eq} = 99.8$ dBA

Simple averaging would correspond to q=6 (2).

Fig. 3: Crusher Operator Histogram over the whole working period, noise exposure index and equivalent continuous sound level.

act are drawn parallel to the base line with a coloured pencil.

4. With the mechanical integrator, the total time for which the noise level is at each selected value, 90, 92, ..., 115 dBA, is integrated step by step (Figs. 2 and 3). If the average recorded level is between levels, it is assigned to the higher level. Total time is expressed in minutes.
5. The values are transferred to the sheet of Fig. 1, and the evaluation is made according to the OSHA exposure limits (Table 1).

It is of course immaterial, for this purpose, whether noise levels are referred to a linear or logarithmic scale on paper tape.

The results of measurement of noise levels versus time are put into the noise survey form and the exposure value for each level is read on the upper horizontal line of the form. The exposures are added with the Mechanical Integrator and the total OSHA mixed exposure index, NEI, is read off on the upper scale (Fig. 1).

If the exposure is greater than 100%, slider No. 1 is used as a marker for the excess over 100% and the adding is continued. The complete hundreds are entered in the column "Over 100%", and the remainder is recorded in the table. These values are added upon the final integration of the exposure value.

The total time T is obtained directly from numerical data or is read from the instrument used. Evaluation can be done directly from the form used for calculating NEI with the mechanical integrator. An integrator is placed on the lowest horizontal edge of the table. The time is read from the table and the timed values of each level are added using slider No. 2. Slider No. 1 is used as a pointer to aid in the addition (Fig. 1).

4. 2. Evaluation of the Equivalent Continuous Sound Level

From the form "Method of Calculating OSHA Mixed Exposure Index", the value of NEI in percent and T in hours and minutes, are transferred onto the nomogram, "Method of Calculating Equivalent Continuous Sound Level" (Fig. 1). The nomogram consists of three parallel scales so graduated that a straight line which joins graduations on two of the scales will cut the third scale at a value that satisfied as equation of the form (4, 5 and 6):

$$f_1(u) + f_2(v) = f_3(w) \qquad \text{(Eq. 3)}$$

In Equation 2 the integral represents the noise exposure integrated over the time T according to the OSHA code. It is therefore proportional to NEI and thus Equation 2 may be written:

$$L_{eq} = k_1 \log_{10} (NEI/T) + k_2, \text{ or}$$

$$L_{eq} = k_1 \log_{10} NEI - k_1 \log_{10} T + k_2 \qquad \text{(Eq. 4)}$$

Equation 4 is the basis for the nomogram connecting L_{eq} on a linear scale with NEI and T on logarithmic scales, since it is of the same form as Equation 3, with $f_1 (L_{eq}) = L_{eq} - k_2$, $f_2/T = k_1 \log_{10} T$ and $f_3 (NEI) = k_1 \log_{10} NEI$.

If NEI is greater than 4000%, it is necessary to divide NEI and T by the same appropriate number before entering the nomogram. Also, if T is less than one minute, it is necessary to multiply T and NEI by an appropriate number before entering the nomogram to read L_{eq}.

5. ACCURACY OF THE GRAPHICAL METHOD

The accuracy of the graphical method rests basically on the geometric accuracy with which the scales are drawn. The normal eye is capable of seeing spaces of 0.1 mm, but it has limited capabilities when it comes to interpolation (5).

With reference to Figs. 1 and 3, the results for the Exposure Index and the Equivalent Continuous Sound Level are in satisfactory agreement, considering the errors normally associated with noise measurement in a mine environment (Table 2).

TABLE 2

Comparison of Results of Noise Exposure Index at the Crusher Operator's Ear

Method of Calculating	Exposure Index	L_{eq} (dBA)	ΣTime* (h)
Standard	1.66	99.8	3.31
Graphical	1.65	100.3	3.20

* exposure period

6. CONCLUSIONS

A simple graphical method has been developed for calculating the Noise Exposure Index and the Equivalent Sound Level, based on measurements made during sampling periods. The measurement technique is simple and the evaluation of the data is simplified and accessible to everyone. The accuracy of results is as good as that obtained by more complex numerical methods (Fig. 3). The method can be used to evaluate L_{eq} when specialized measuring instruments are not available. The time required to evaluate typical noise data is reduced from days to hours, (by a factor of 10 or more), as compared to a purely numerical method.

7. ACKNOWLEDGEMENTS

The author acknowledges the contribution of Dr. R. Tervo, Acting Manager, Elliot Lake Laboratory, and Dr. G.D. Just, Senior Lecturer in Mining Engineering, University of Queensland, Australia, at the time National Research Council Post-doctoral Fellow, Elliot Lake Laboratory.

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Simple Graphical method of evaluation of the noise exposure index and the equivalent continuous sound level

1976

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71 (797) p 111, 1978

ESSAIS D'UN CASQUE DE SURVEILLANCE DE L'EXPOSITION AU BRUIT

par

R. Seymour*

RÉSUMÉ

Des essais ont été menés avec un appareil de surveillance de l'exposition au bruit incorporé dans un casque de façon que le microphone soit placé près de l'oreille du travailleur, avec un minimum de gêne pour ce dernier. Nous avons effectué des mesures en plaçant le casque dans différentes positions par rapport à la source de bruit et en faisant varier le niveau sonore de façon à couvrir toutes les conditions de fonctionnement.

Les indications fournies par le casque ont été comparées avec les résultats obtenus à l'aide de deux autres appareils de surveillance et avec les prévisions. Au début, les indications fournies par le casque étaient élevées et nous avons attribué ce résultat à la réflexion du son par le casque dans le microphone. Pour éliminer ce phénomène, nous avons placé un absorbant acoustique autour du microphone sur le casque.

Lors de la deuxième série d'essais, le casque de surveillance du bruit a donné des résultats relativement précis. Il est donc possible d'utiliser le casque modifié à l'aide de l'absorbant acoustique pour mesurer l'exposition au bruit de la personne portant le casque.

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* Étudiant, université de Waterloo, en stage au Laboratoire d'Elliot Lake, Laboratoires de recherche minière. Centre canadien de la technologie des minéraux et de l'énergie, ministère de l'Énergie, des Mines et des Ressources, Elliot Lake (Ontario)

Avant que le casque soit prêt à être utilisé, il convient d'étudier différents types de matériau absorbant ainsi que la façon de poser ce matériau autour du microphone. Enfin, il convient aussi de vérifier le comportement du casque final dans les conditions les plus difficiles.

TESTS OF A NOISE EXPOSURE MONITOR HELMET

by

R. Seymour*

SUMMARY

Tests were conducted of a noise exposure monitor built into a hard hat designed to place the microphone near the ear with a minimum of inconvenience to the worker. The tests were made by taking measurements with the hat in different positions relative to the noise source, and with the sound level being varied to cover the complete range of operation.

The output from the hat was recorded along with results from two other monitors. Readings from the monitor hat were compared with the readings from the other monitors, and with expected readings. Initially the meter reading was high and this was thought to be due to sound reflecting off the helmet into the microphone. To eliminate this, sound absorption foam was placed around, and forward of, the microphone on the helmet.

When the tests were rerun, reasonably accurate results were obtained with the noise monitor. Therefore, the original design, when modified by the sound absorption foam, may be used to measure the noise exposure of the person wearing the hat.

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* Student, Waterloo University, on work term at Elliot Lake Laboratory, Mining Research Laboratories, Canada Centre for Mineral and Energy Technology, Department of Energy, Mines and Resources, Elliot Lake, Ontario.

Before this hat is ready for general use, tests should be made of the suitability of various sound absorption materials, and of the best placement of this material around the microphone. Any final design should also be tested under the most rugged conditions to see how well it stands up to abuse.

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Octave Band Analysis Data for Noise Monitor Hat Lined with Poly-urethane-ether APO 35 ---------- 5A

INTRODUCTION

A major occupational health hazard is the exposure of workers to excessive levels of noise produced by heavy industrial equipment, which can cause permanent hearing damage. Thus, recent emphasis has been placed on the monitoring of occupational noise exposure. The present technique uses a commercial noise exposure monitor which gives a measure of the noise level integrated over an interval of time. Noise monitors currently in use are in accordance with occupational noise exposure regulations set out in the Occupational Safety and Health Act (OSHA).

These monitors often hamper the worker. This report deals with tests of a design by Miron Savich, Research Scientist, Elliot Lake Laboratory, CANMET, E.M.R., which would place the monitor in the hard hat, where it would not hinder the worker. The measurement accuracy of this design was the subject of these tests.

EQUIPMENT AND TEST PROCEDURE

The tests used a model 1944 noise exposure monitor produced by General Radio. The specifications are in Appendix I. The monitor was taken apart and the electronic components were attached to the right side of the hat above the ear. The battery and microphone were attached to the left side of the hat over the ear, as shown in Fig. 1.

The sound level is measured in dBA - the sound level in decibels given 'A' weighting. 'A' weighting approximates the sound level in the ear, since the apparent loudness with which noise is heard varies both with sound pressure and frequency. Fig. 2 shows the frequency response characteristics

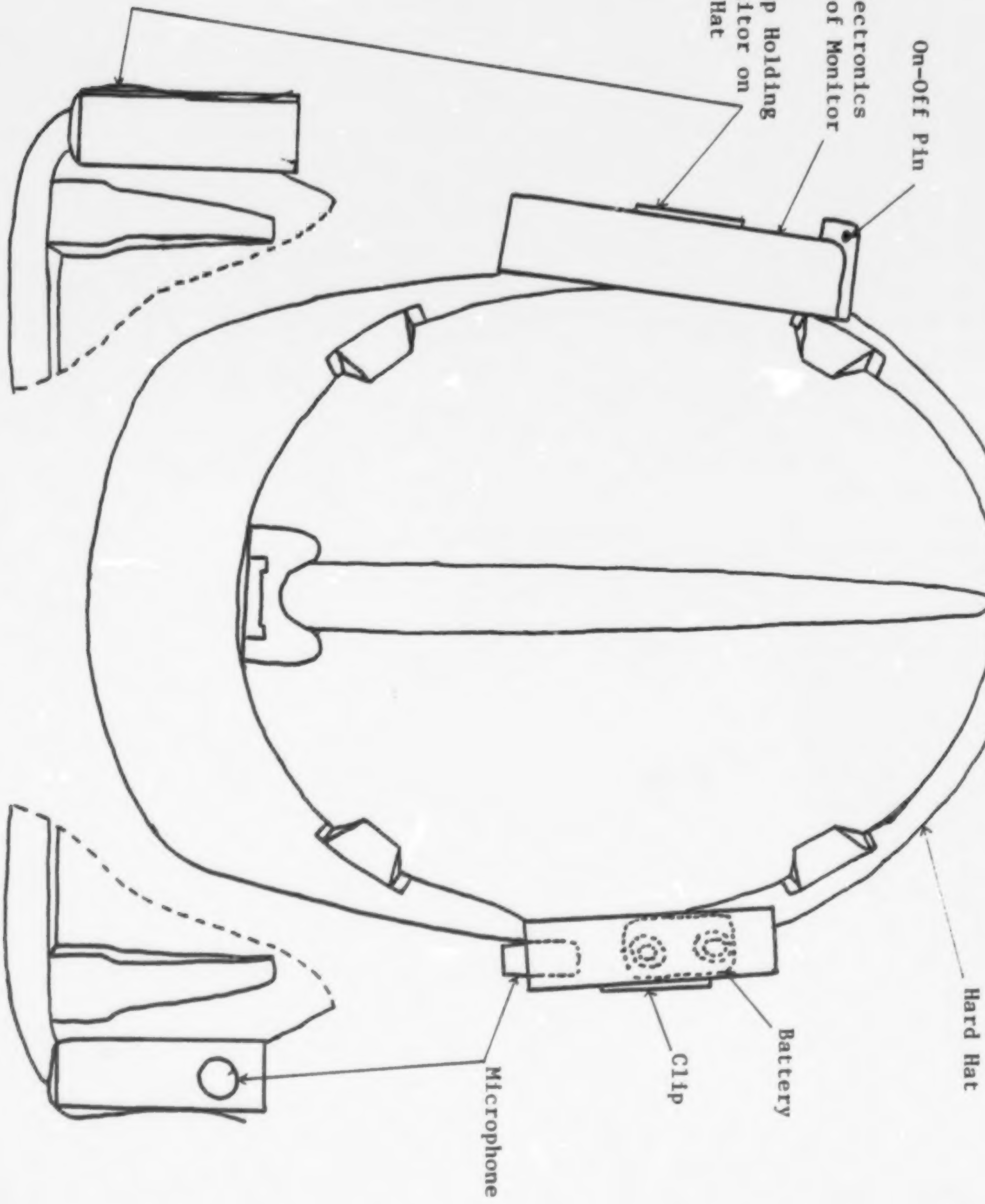
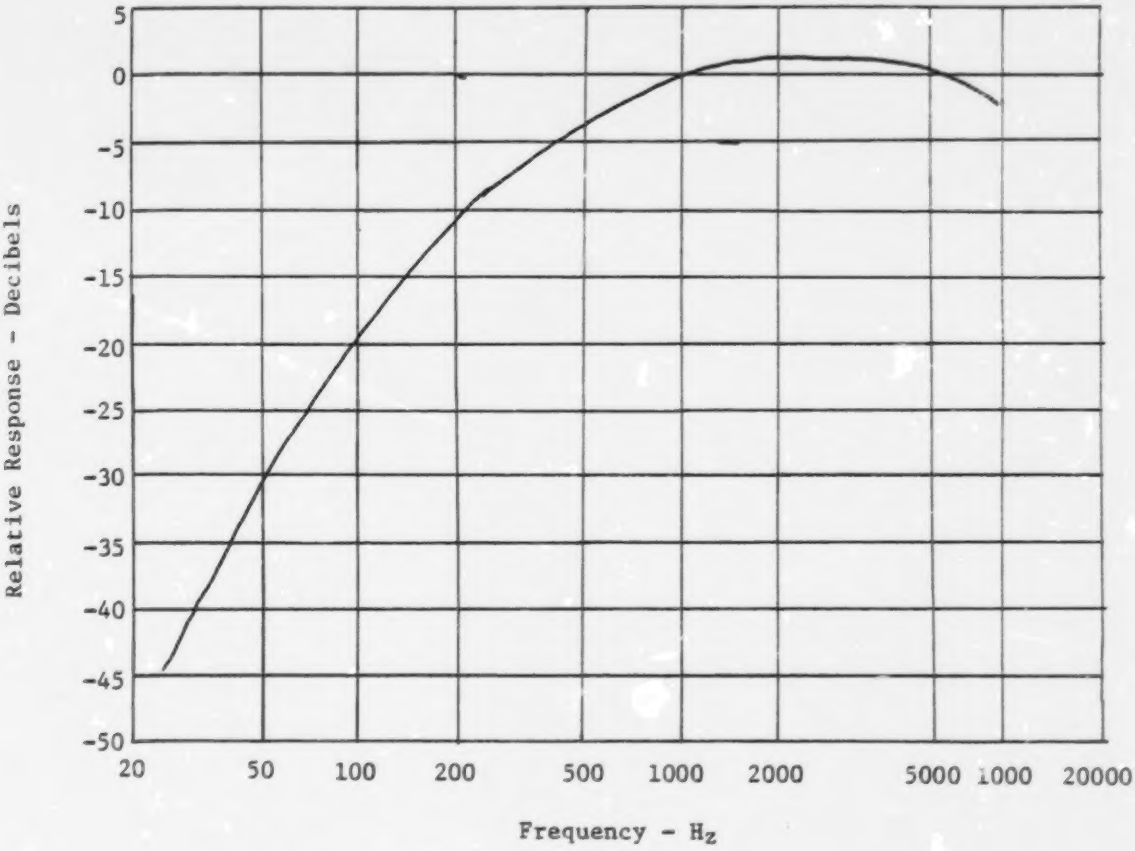

On-Off Pin
Electronics of Monitor
Clip Holding Monitor on Hat
Hard Hat
Battery
Clip
Microphone

Fig. 1: Noise Monitor Hat

Fig. 2: FREQUENCY RESPONSE FOR SLM 'A WEIGHTING CHARACTERISTICS



Frequency-Response Characteristics in the American National Standard Specification for Sound-Level Meters, ANSI-SI 4-1971 (From Peterson and Gross).

of the monitor for 'A' weighting. The monitor output gives percent exposure with 100% representing the permissible exposure for one day. Table 1 gives the time at various sound levels for 100% exposure. A rule of thumb is, for every 5 dBA increase in sound level, the permitted exposure time halves.

There were two other noise exposure monitors used external to the hat, both model GR 1944's. A sound level meter was placed on a stand at a vertical angle of 60°, next to the left ear. The output of the sound level meter was fed into a small graphic recorder. Fig. 3 shows the position of the microphones for these tests.

The physical setup of the tests had the subject wearing the hat and ear muffs, and sitting 1-meter away from a speaker. The speaker received the amplified output of a random noise generator. Measurements were taken with the subject facing 0°, 90°, 180° and 270° relative to the speaker, and with sound levels of, 85, 90, 95, 100, 105, 110 and 115 dBA.

For each measurement after the sound level was set, an octave band analysis was done on the noise. This involves the measurement in decibels of the audio range divided into 10 bands, whose centre frequencies were 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000 and 16000 H_z, each band covering a 2 to 1 frequency range. Analysis involved measurement of the sound level of each of these bands. The output of the graphic recorder was read in order to obtain an average level.

The tests were run for 30 minutes each at the 85, 90, 95, 100 and 105 dBA levels, and for 15 minutes each at the 110 and 115 dBA levels.

TABLE 1

OSHA

Sound Level (dBA)	Time Permitted (Hours)	Sound Level (dBA)	Time Permitted (Hours)
85	16.0	101	1.733
86	13.933	102	1.517
87	12.133	103	1.317
88	10.55	104	1.15
89	9.183	105	1.0
90	8.00	106	0.867
91	6.967	107	0.75
92	6.067	108	0.667
93	5.283	109	0.567
94	4.6	110	0.5
95	4.0	111	0.433
96	3.483	112	0.383
97	3.033	113	0.333
98	2.633	114	0.283
99	2.3	115	0.25
100	2.0		

Sound Level vs Time Permitted

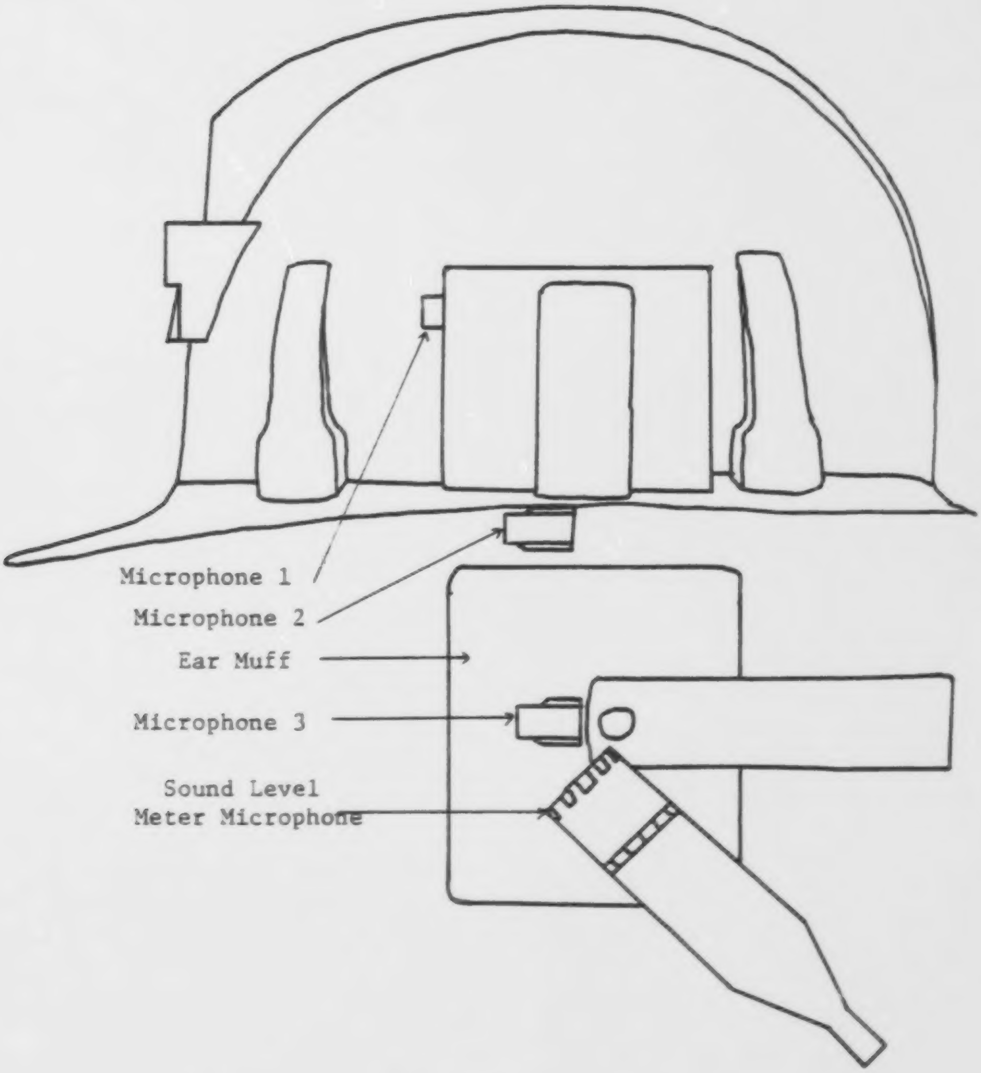

Microphone 1
Microphone 2
Ear Muff
Microphone 3
Sound Level
Meter Microphone

Fig. 3: Positioning of Microphones for Tests

The monitors were read and these readings were extrapolated to the maximum exposure time of the level at which the reading was taken.

ANALYSIS AND DISCUSSION

When the tests were completed the percentage exposures for the four positions were averaged for each level. The same was done for the sound levels of each band from the octave band analysis. The sound level is in decibels, which is a logarithmic scale,so it must be converted to the power it represents, averaged, and then converted back. The average sound levels from the bands were combined to calculate the 'A' weighted total sound level. Appendix II gives the formulas for working in decibels. The 'A' weighted sound level calculated in this way is a good estimate of the sound level at which the analysis was done. This provides a check for the measured sound level. In all cases the estimated level was within ± 1 dB of the measured level.

The results of the test can be seen in Table 2. The percentage exposure from the third monitor for 85 dBA is extremely low. This is due to the lower range limit of the monitor being set slightly higher than 85 dBA. These data have, therefore, been left out of the analysis.

All readings were higher than expected, and the two monitors with microphones on the hat were generally higher than the third, which was on the ear muff by the ear.

The readings from the internal monitor were much higher than either of the other two when the subject was facing the noise source. On this evidence it is believed that the high readings were caused by reflection of

TABLE 2

Test of Noise Monitor Hat Not Lined

Time (h)	Sound Level (dB)		Noise Exposure Values in Percent			
				Noise Dosimeter GR-1944		
	Meas.	Est'd.*	Expecting	(1) Noise Monitor Hat	(2) On the Brim of the Hat	(3) At Experimenter's Ear
16	85.0	85.5	100	136	128	8
8	90.0	90.2	100	148	144	132
4	95.0	95.6	100	144	138	128
2	100.0	100.2	100	144	128	123
1	105.0	104.8	100	158	146	127
.5	110.0	110.0	100	177	186	143
.25	115.0	114.4	100	121	156	127
				$\bar{x} = 147$	$\bar{x} = 147$	$\bar{x} = 130$†

*Estimate comes from octave band analysis. For data see Appendix 3.

†Data from level 85 excluded, see text.

sound off the hard hat in the area of the microphone. Since the microphone holder is at 90° to the hat, i.e., there is a corner, this will act as a sound trap, compounding the effect.

The hard hat has a rigid shell, so another possibility is that sound striking the helmet is transmitted by the shell to the microphone. This would result in the slightly higher than normal reading for the monitors with microphones on the hat.

To eliminate these two problems, sound absorption foam was glued to the hat in the area of the microphone. This would absorb sound striking the hat around the microphone rather than reflect it, and since the foam fits over the microphone, it would stop any vibrations being released in the area of the microphone. Fig. 4 shows the placement of the foam on the hat.

Two types of sound absorption foam were tried, Eccodamp MG* and Poly-urethane-ether AOP 35. For each of these, the test procedure used was the same as the one previously used. The results of these tests can be seen in Tables 3 and 4.

With the Eccodamp MG foam the two external monitors gave close to the same average reading as with the hat not lined. The readings from the internal monitor decreased and was more in line with the third monitor. This showed a design improvement as the third monitor had its microphone by the ear, and not attached to the hat. Since only the internal monitor microphone was protected by foam these results are consistent.

The Poly-urethane-ether AOP 35 resulted in an unexplained decrease

---

* Product of Emerson and Caming Inc., Canton, Mass.

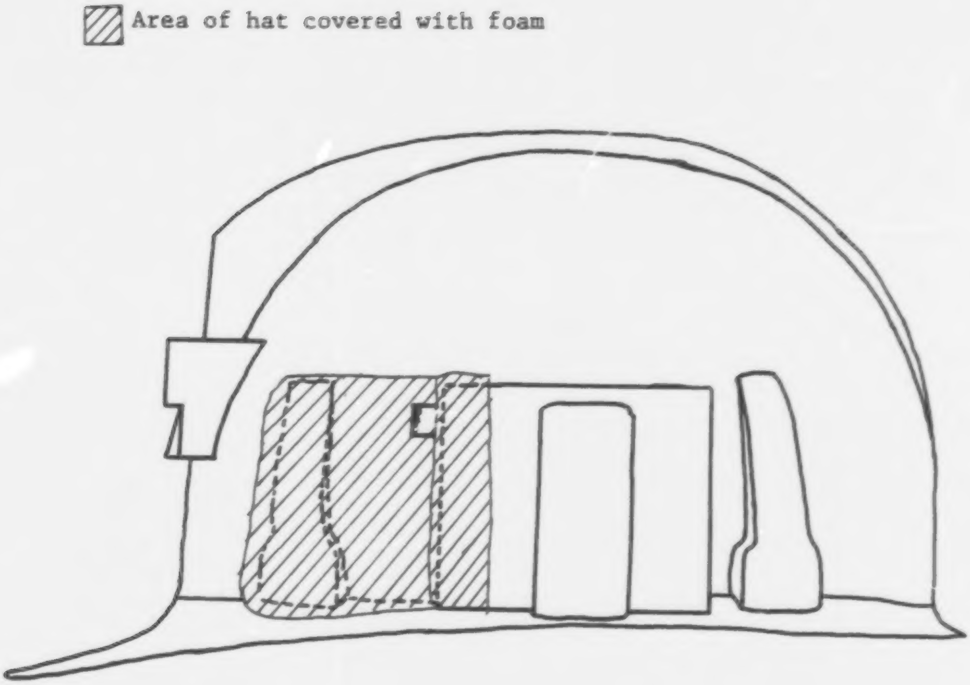

▨ Area of hat covered with foam

Fig. 4: Positioning of Foam on Hat

The foam covered area starts slightly behind the microphone and is extended forward till the curve of the hat is such that sound cannot be reflected to the microphone.

TABLE 3

Test of Noise Monitor Hat Lined with Poly-urethane-ether AOP 35

Time (h)	Sound Level (dB)		Noise Exposure Values in Percent			
				Noise Dosimeter GR-1944		
	Meas.	Est'd.*	Expecting	(1) Noise Monitor Hat	(2) On the Brim of the Hat	(3) At Experimenter's Ear
16	85.0	85.6	100	100	100	0
8	90.0	90.7	100	110	130	110
4	95.0	95.2	100	130	143	133
2	100.0	100.3	100	113	135	118
1	105.0	105.6	100	118	128	116
.5	110.0	110.3	100	111	116	108
.25	115.0	114.7	100	95	95	103
				$\bar{x} = 111$	$\bar{x} = 122$	$\bar{x} = 115$†

*Estimate comes from octave band analysis. For data used, see Appendix 3.
†Data from level 85 excluded, see text.

TABLE 4

Test of Noise Monitor Hat Lined with Eccodamp MG Foam

Time (h)	Sound Level (dB)		Noise Exposure Values in Percent			
				Noise Dosimeter GR-1944		
	Meas.	Est'd.*	Expecting	(1) Noise Monitor Hat	(2) On the Brim of the Hat	(3) At Experimenter's Ear
16	85.0	85.9	100	140	130	0
8	90.0	90.6	100	120	155	125
4	95.0	95.0	100	140	145	143
2	100.0	99.9	100	140	140	133
1	105.0	104.5	100	143	143	126
.5	110.0	109.6	100	137	136	129
.25	115.0	114.4	100	137	159	137
				$\bar{x}$ = 140	$\bar{x}$ = 144	$\bar{x}$ = 131†

*Estimate comes from octave band analysis. For data see Appendix 3.
†Data from level 85 excluded, see text.

in all readings. This should not invalidate the results. The ratio of the average values for the two external monitors for three sets of results is presented in Table 5, and this shows that while the results are lower for the Poly-urethane-ether, the ratio of these results are constant within tolerable limits. This validates applying any comparison made between monitors to the other results.

TABLE 5

RATIOS OF MONITOR 2 TO MONITOR 3

	Monitor 2	Monitor 3	Monitor 2/ Monitor 3
Non lined	147%	130%	1.13
Poly-urethane-ether	122%	115%	1.06
Eccodamp	144%	130%	1.11

Poly-urethane-ether also caused a decrease in the readings from the internal monitor to a level where the average value was slightly lower than the readings from the microphone over the ear, as had been expected.

CONCLUSION

The original noise exposure monitor hat without sound absorption material did not give the accuracy required. With the addition of sound absorption foam around the microphone the noise exposure monitor hat gave satisfactory results. The results show the noise exposure monitor hat to be a reliable instrument for measuring noise exposure with a minimum of inconvenience to the user.

RECOMMENDATIONS

It was found that sound absorption foam was required to make the noise exposure monitor hat a reliable instrument. Many other types of sound absorption materials exist which would do the job as well or better. Many of these materials would be unsuitable in a working environment. In order to optimize the design, different types of sound absorbing materials should be tested, both in sound absorption qualities and for suitability to the working environment.

Before any design is finalized, it should be tested to determine its ability to withstand shocks. This is necessary if the hats are to be used for any length of time in an industrial operation.

BIBLIOGRAPHY

1. Peterson, A. P. G. and Gross, E. F. Jr., Handbook of noise measurement; General Radio Company; 1977.
2. Type 1944 moise dosimeter instruction manual; General Radio Company; 1977.

APPENDIX I

Specifications for Type 1944 Noise Dosimeter

Specifications

NOISE-EXPOSURE MONITOR

Noise-Level Exposure: The Exposure Monitor (1944-9704) integrates noise in accordance with ISO Recommendation R1999 (May 1971). The integrated level is stored in a low-power MOS-type counter that is permanently connected to the battery. The indicated noise-exposure index doubles corresponding to a 3-dB increase in input level. The maximum index that can be accumulated before resetting the monitor is 999, corresponding to an 8h exposure at 100 dB.

Sound-Level Range: 80 to 120 dBA (re 20 $\mu N/m^2$). Peak sound-pressure level before overload is 140 dB.

Weighting: "A" in accordance with ANSI Standard S1.4-1971 Type 2 and IEC Publication 123,1961.

Accuracy: At 105 dB, 1 kHz, 23°C, ±0.5 dB. Temperature coefficient of sensitivity is about +.03dB/°C. LINEARITY: ±.06dB at 1kHz, from 80 to 120 dBA, with reference to the 105 dBA level. STANDARDS: Satisfies all applicable sections of ANSI S1.4-1971 for Type 2 Sound-Level Meters and IEC R123,1961, including acoustical, amplifier, weighting, and detection specifications. DETECTOR: True rms response with "slow" speed in accordance with ANSI S1.4-1971 and IEC Publication 123,1961. Crest-factor capacity at full scale (120 dBA) is greater than 13 dB. 120 dBA EXCEEDED: If 120-dBA sound level is exceeded, this information is stored in the monitor unit and read out on the indicator.

Microphone: Ceramic type.

Environmental: TEMPERATURE: -10 to 45°C operating; -40°C to +60°C storage with batteries removed. HUMIDITY: Up to 90% RH at 40°C. EFFECT OF MAGNETIC FIELD: The monitor will not accumulate any count when placed in a 50- or 60-Hz magnetic field of up to 150 oersteds.

Power: One 9V battery (Burgess 2U6 or equivalent) supplied, provides about 300 h operation. MOS counter and latch storing data are permanently connected to battery and can store accumulated percentage and 120 dBA limit for shelf life of battery.

Mechanical: Shielded metal case. DIMENSIONS(wXhXd): 56 X 124 X 23 mm. WEIGHT: 0.21 kg

NOISE EXPOSURE INDICATOR

Noise Exposure Index: The Noise Exposure Indicator (1944-9705) converts the binary information stored in the Monitor Unit to an index number that is read on a light-emitting diode display. The indicator reads index numbers up to 999 corresponding to an equivalent continuous exposure of 100 dBA. Monitor latches at 999 for accumulations exceeding this amount.

Readout: 1 to 999 on light-emitting diode display in increments of 1. (Corresponds to a resolution of .04 dB at 90 dB SPL). 120 dBA EXCEEDED: A light shows when 120 dBA has been exceeded (stored in Monitor Unit).

Calibration: A sound-level calibrator is included in the indicator. The calibrator produces a pressure of 105 dBA for a period of 27 s corresponding to an accumulation of 3. BATTERY CHECK: A meter is provided for checking batteries in the monitor and indicator units.

Environment: TEMPERATURE: -10 to 45°C operating: -40°C to +60°C storage with batteries removed. HUMIDITY: Up to 90% RH at 40°C.

Power: Four 1.5 V "C" cells supplied, provide 20 h continuous life. NORMAL SERVICE LIFE: >6 months.

Mechanical: DIMENSIONS(wXhXd): 280X186X54 mm. WEIGHT: 1.42 kg.

U.S. Patent 3,681,618.

Description	Catalog Number
1944-I Dosimeter (includes Monitor and Indicator)	1944-9703
1944-I Noise-Exposure Monitor	1944-9704
Spare Battery (monitor uses 1)	8410-3200
1944-I Noise Exposure Indicator	1944-9705
Spare Battery (indicator uses 4)	8410-1500

* From Instruction Manual Type 1944 Noise Dosimeter

APPENDIX II

FORMULAS FOR WORKING WITH DECIBELS

Adding decibels

$$L_T = 10 \log (10^{L_1/10} + 10^{L_2/10} + \ldots + 10^{L_N/10})$$

Subtracting decibels

$$L_T = 10 \log (10^{L_1/10} - 10^{L_2/10} - \ldots - 10^{L_N/10})$$

Averaging decibels

$$L_{ave.} = 10 \log \left[(10^{L_1/10} + 10^{L_2/10} + \ldots + 10^{L_N/10})/N\right]$$

Calculating 'A' weighted sound level from octave band levels

$$L_A = 10 \log (10^{(L_{31.5} - 39)/10} + 10^{(L_{63} - 26)/10} + 10^{(L_{125} - 16)/110}$$

$$+ 10^{(L_{250} - 9)/10} + 10^{(L_{500} -3)/10} + 10^{(L_{1k})/10} + 10^{(L_{2k}+1)/10}$$

$$+ 10^{(L_{4k} - 1)/10} + 10^{(L_{8k} - 1)/10}$$

where: $L_1, L_2, L_3 \ldots L_N$ = sound levels in decibels being added

L_T = total sound level in decibels

$L_{ave.}$ = average sound level in decibels

N = number of sound levels being used

L_A = calculated A weighted sound level

$L_{31.5}, L_{63} \ldots L_{8k}$ = octave band levels in decibels

APPENDIX III

Octave Band Analysis Data for Nonlined Noise Monitor Hat

Frequency in Hz									Sound Level (dBA)	
31.5	63	125	250	500	1K	2K	4K	8K	Meas.	Est'd.
72.8	72.8	72.8	72.8	73.9	79.8	81.5	76.1	73.0	85.0	85.5
72.5	72.5	72.5	72.5	76.4	84.2	86.8	80.4	73.9	90.0	90.2
72.5	72.5	72.5	72.5	79.1	89.2	92.6	85.3	72.2	95.0	95.6
72.5	72.5	72.5	72.8	83.5	94.1	96.9	91.0	79.7	100.0	100.2
71.5	71.5	71.5	72.9	88.1	99.1	101.3	95.5	85.8	105.0	104.8
81.9	81.9	81.9	82.4	95.0	104.8	106.4	99.3	92.3	110.0	110.0
82.5	82.5	82.5	84.0	99.4	108.7	111.3	103.2	92.5	115.0	114.4

APPENDIX III cont'd.

Octave Band Analysis for Noise Monitor Hat Lined with Eccodamp MG

Frequency in H_z									Sound Level (dBA)	
31.5	63	125	250	500	1k	2k	4k	8k	Meas.	Est'd.
72.5	72.5	72.5	72.5	73.5	78.9	81.5	76.6	72.9	85.0	85.9
72.5	72.5	72.5	72.5	75.8	83.4	87.7	80.4	73.9	90.0	90.6
72.4	72.4	72.4	72.4	79.4	88.3	91.7	86.2	76.4	95.0	95.0
72.4	72.4	72.4	72.6	84.0	93.8	96.8	89.0	78.9	100.0	99.9
72.5	72.5	72.5	73.4	88.7	98.6	101.0	95.3	83.3	105.0	104.5
82.4	82.4	82.4	82.6	94.7	103.6	106.4	99.6	88.9	110.0	109.6
82.5	82.5	82.5	83.8	100.1	108.4	111.1	104.4	92.6	115.0	114.4

APPENDIX III cont'd.

Octave Band Analysis for Noise Monitor Hat Lined with Poly-urethane-ether APO 35

Frequency in H_z									Sound Level (dBA)	
31.5	63	125	250	500	1k	2k	4k	8k	Meas.	Est'd.
72.9	72.9	72.9	72.9	73.8	79.3	81.7	76.8	73.1	85.0	85.6
73	73	73	73	75.8	84.3	87.5	81.3	74.0	90.0	90.7
72.6	72.6	72.6	72.6	79.3	89.4	91.9	85.2	75.7	95.0	95.2
72.5	72.5	72.5	72.8	84.3	94.3	97.1	90.4	78.9	100.0	100.3
72.8	72.8	72.8	73.8	89.7	100.0	102.4	94.1	83.2	105.0	105.6
82.9	82.9	82.9	83	94.5	104.2	107.2	99.3	93	110.0	110.3
82.9	82.9	82.9	83.6	98.6	108.6	111.8	103.0	93.9	115.0	114.7

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Tests of a noise exposure monitor helmet

1977

UN PROGRÈS IMPORTANT DANS LES INSTRUMENTS DE SURVEILLANCE DU BRUIT

par

M.U. Savich*

RÉSUMÉ

Les nouveaux instruments Metrosonics ont été conçus dans le but de permettre l'obtention de toutes les données requises pour l'établissement de programmes de lutte contre le bruit dans les mines :

1) le Metrologger 306 est excellent pour des mesures brèves de l'indice d'exposition au bruit et pour les essais de casques antibruit;
2) le système Metrologging 301/651 devrait être utilisé comme instrument de base car il permet d'obtenir toutes les données relatives à l'environnement minier à partir de données historiques entrées dans un ordinateur.

On peut obtenir différents taux d'échange, descripteurs, ligne de base, etc. en changeant les modules du programme (PROM).

Ces instruments seront utilisés dans un projet conjoint avec la Direction de la santé et de la sécurité dans les mines du ministère du Travail de l'Ontario (MOL).

Mots-clés : Bruit, exploitation minière, surveillance, instruments.
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A SIGNIFICANT ADVANCE IN NOISE MONITORING INSTRUMENTATION

by

M. U. Savich *

ABSTRACT

Metrosonics newest instruments are part of the aim to obtain the full information required for the establishment of control programs for the mining environment:

1) the 306 Metrologger is excellent for short measurements of noise exposure index (NEI), and for testing ear muff efficiency; and
2) the 301/651 Metrologging System should be used as a basic instrument, because from time history data fed through a computer all results pertaining to the mining environment can be obtained.

Computation of different exchange rates, descriptors, baseline, etc. can be obtained by changing the program modules (PROM).

These instruments will be used in a joint project with Mining Health and Safety Branch Ministry of Labour of Ontario (MOL).

Key words: Noise, Mining, Monitoring, Instrumentation.

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1. INTRODUCTION

The aim of the short measurements done at Toronto's International Airport was to get acquainted in detail with the new Metrosonics Inc. instruments. These instruments will be used in a joint project with Mining Health and Safety Branch Ministry of Labour of Ontario.

2. DEFINITIONS OF NOISE EXPOSURE INDEX AND EQUIVALENT CONTINUOUS SOUND LEVEL

The simplest measuring problem occurs when the sound level is constant, then L_{eq}* is equal to the reading of a sound level meter. When the sound level is not constant, the direct indication of L_{eq} requires a specialized instrument.

In this case the Noise Exposure Index (NEI) may be specified as being the constant sound level for the time duration.

The noise exposure has led to several standards and recommendations in North America (Fig. 1). Among these are:

1) OSHA +: Walsh-Healey Act (USA federal law concerning hearing conservation in government supplying industry) used in all North America.
2) ISO ‡: Recommendation R 1999: Assessment of occupational noise exposure for hearing conservation purposes, used only in British Columbia, Canada.

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* The equivalent continuous sound level.

+ The Occupational Safety and Health Act (U. S. A.).

‡ The International Standards Organization.

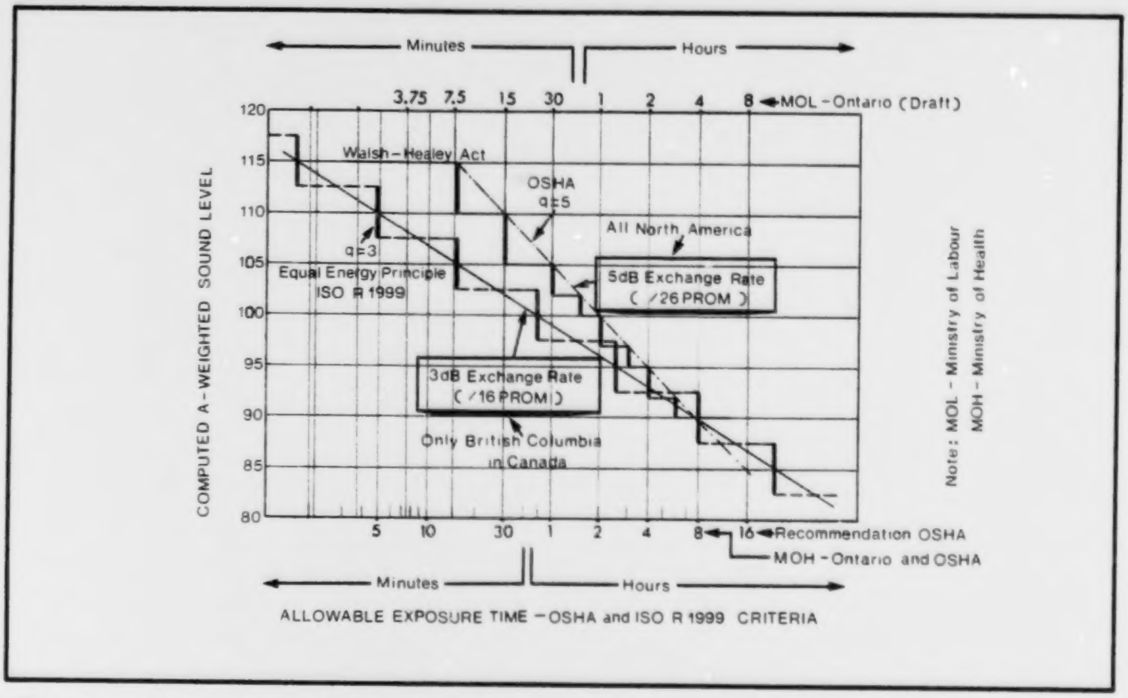


Fig. 1: The relationship between sound level and duration for the Walsh-Healey Act and ISO R 1999.

OSHA operates with the parameter q = 5, i.e., 5 dBA increase of sound level corresponds to half the duration. ISO has q = 3 (3 dBA increase for halving of duration). Simple averaging would correspond to q = 6.

To determine noise exposure index and equivalent continuous sound level, the numerical value of parameter q and the varying sound level p(t) within the considered time period T should be evaluated. L_{eq} is defined mathematically by (1):

$$L_{eq} = \frac{q}{\log_{10} 2} \log_{10} \left[\frac{1}{T} \int_0^T \left(\frac{p(t)}{p_o} \right)^{\frac{20 \log_{10} 2}{q}} dt \right] \qquad \text{Eq. 1}$$

where q has different values:

	q	$\frac{q}{\log_{10}2}$	$\frac{20\log_{10}2}{2}$
OSHA	5	16.60	1.20
ISO	3	9.97	2.01
Simple averaging	6	19.93	1.00

T is the total sampling period in hours;

p(t) is the instantaneous A-weighted sound pressure in Pa (pascal);

po is the reference r.m.s. sound pressure, 2×10^{-5} Pa; and

t is the time in hours.

Safe limits for noise exposure are often referred to as hearing conservation criteria. The guidelines presently in use in Canada, except British Columbia, are those adopted by the OSHA and the American Conference of Governmental Industrial Hygienists (ACGIH) for 1971, as follows (Table 1).

When the noise consists of different dBA noise levels throughout the day, the combined exposure is controlled by calculating from Table 1.

3. INSTRUMENTS

All noise dosimeter manufacturers made an effort to have their instruments meet existing regulations and to give final results: Noise Exposure Index (NEI). In practice this was shown to be inadequate because the following factors were not considered:

1) Sound Pressure Level (SPL), so that we don't have to purchase a separate instrument for its measurement.

TABLE 1

Noise Exposure Limits for a Normal 8-Hour Working Day

Duration per Day Hours	Sound Level dBA Slow Response			
	OSHA	ACGIH	MOH	MOL
16	85*	-	-	80★
8	90	90	90	85
6	92	92	92	-
4	95	95	95	90
3	97	97	97	-
2	100	100	100	95
1.5	102	102	102	-
1	105	105	105	100
0.75	-	107	107	-
0.50	110	110	110	105
0.25	115	115	115	110
0.125	-	-	-	115

* Recommendation.
★ Draft.

NOTE: Exposure to impulsive or impact noise should not exceed a 140 dBC peak sound pressure level.

2) Maximum Level (L_{max}), so to make it possible for us to properly apply personnel hearing protection.

3) Equivalent continuous noise level (L_{OSHA}), the accepted risk of hearing loss (>90 dBA or >85 dBA).

4) Equivalent continuous noise level (L_{eq}), during short time or normal 8-hour working day.

5) Time (T), during L_{OSHA} or L_{eq}.

The Time-Resolved Audio Dosimeter was developed by the Pittsburgh Mining and Safety Research Center of the United States Bureau of Mines (2). During a work shift, each 30-second pulse count is stored in a solid state memory. At the end of the shift the pulse counts can be fed into a graphic plotter or a computer for analysis.

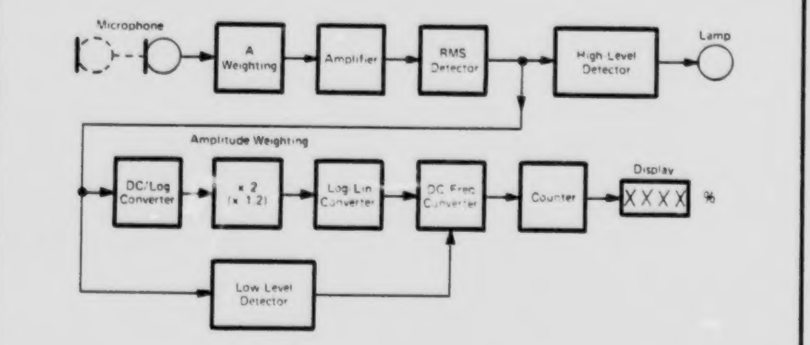
For use by the U.S. Air Force, Loomis Laboratories made roughly 20 dosimeters (3). A large (static) serial memory is provided for the accumulation of the dose counts, and a smaller memory is provided to record the length of time at the over-range level. At the end of the measurement, the dosimeter should be connected to the digital readout unit.

And finally, in Sweden a noise dosimeter has been constructed which measures the time during which a certain present noise level is exceeded (4). The information is recorded on a photographic film and the blackness of the film is a function of the time during which the noise has exceeded the present value.

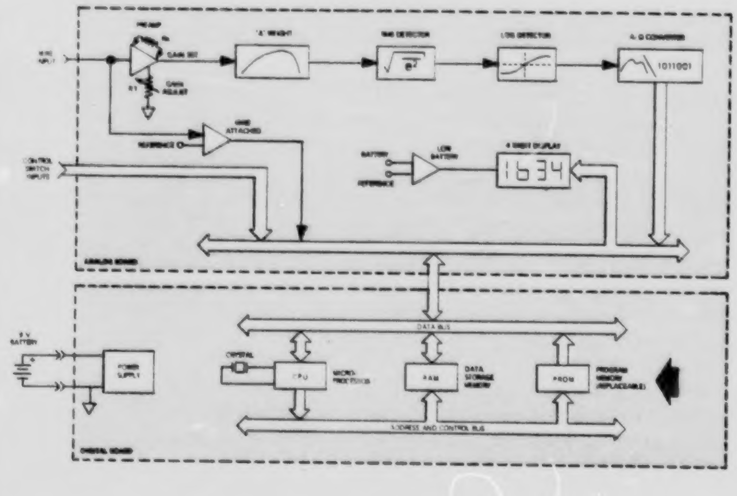
Metrosonics Inc. started in the opposite direction. They constructed an instrument (actually a simplified dosimeter) that gives results which when combined make it easy to calculate the NEI through the numerical or graphical method (Fig. 2).

3.1. 306 Metrologger

The 306 Metrologger digital sound level analyzer is a pocket-size computer designed for automatic sound level analysis over a selected 64 dB range (Fig. 3). The internal computer circuit samples the amplitude, calculates and provides 4 digit displays of SPL, L_{max}, L_{eq} or L_{OSHA}, and the time duration of the sampling period (Fig. 2B). The samples are converted


Microphone
A Weighting
Amplifier
RMS Detector
High Level Detector
Lamp
Amplitude Weighting
DC/Log Converter
x 2 (x 1.2)
Log/Lin Converter
DC/Freq Converter
Counter
Display
XXXX
%
Low Level Detector

A. Noise Dose Meter Type 4424/4425, B and K (5).


GAIN SET
R1
'A' WEIGHT
LOG DETECTOR
1011001
ATTACHED
1634
DATA BUS
9 V BATTERY
POWER SUPPLY
CRYSTAL
CPU
RAM
DATA STORAGE MEMORY
PROM
ADDRESS AND CONTROL BUS

B. 306 Metrologger, Metrosonics Inc. (6).

Fig. 2: Block diagrams.

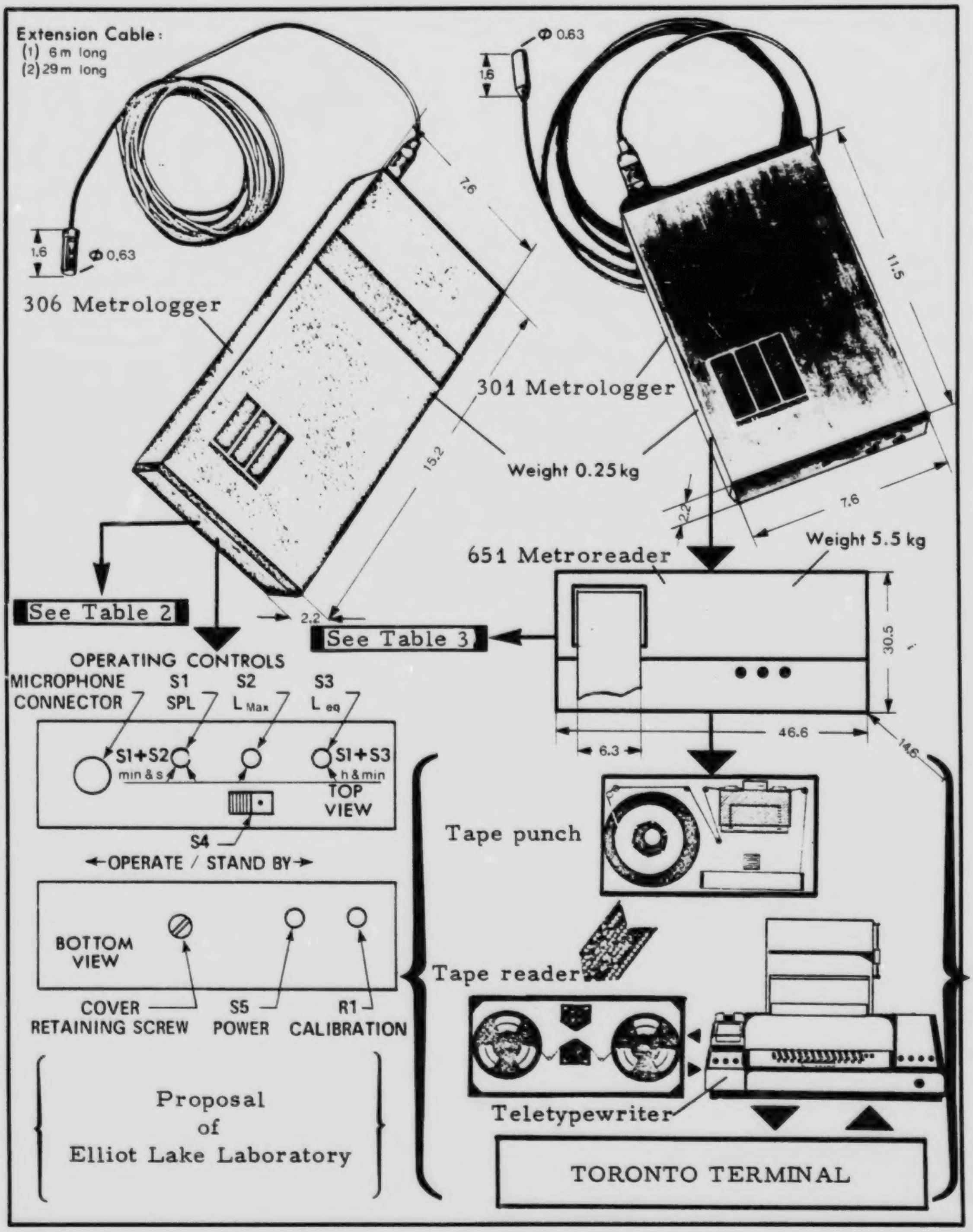

Extension Cable:
(1) 6m long
(2) 29m long
1.6
Φ 0.63
306 Metrologger
7.6
15.2
2.2
Weight 0.25 kg
301 Metrologger
11.5
7.6
2.2
Φ 0.63
1.6
651 Metroreader
Weight 5.5 kg
30.5
46.6
6.3
14.6
See Table 2
See Table 3
OPERATING CONTROLS
MICROPHONE CONNECTOR
S1 SPL
S2 L Max
S3 L eq
S1+S2 min & s
S1+S3 h & min
TOP VIEW
S4
← OPERATE / STAND BY →
BOTTOM VIEW
COVER RETAINING SCREW
S5 POWER
R1 CALIBRATION
Proposal of Elliot Lake Laboratory
Tape punch
Tape reader
Teletypewriter
TORONTO TERMINAL

Fig. 3: Instrumentation for noise investigation in mines.

to digital format and stored. The 306 samples the detected amplitude level 4 times per second. Test duration can be from one second to 252, 750 seconds or 70. 2 hours (252, 750. 25 x 4 = 1, 011, 001) (Fig. 2B). The PROM (Program Modules) replacement feature provides the ability to change the functions of the 306 Metrologger (Table 2). To display L_{max}, press switch S2 on the top panel, and for L_{eq} or L_{OSHA}, press switch S3 on top panel. To display test duration, simultaneously depress switches S1 and S3 on the top panel for hours and minutes or S1 and S2 for minutes and seconds (Fig. 3).

The 306 Metrologger meets the accuracy requirements specified by the American National Standards Institute (ANSI) for a general purpose sound level meter (S1. 4 - 1971, Type 2)*, and is also capable of acoustical calibration in the field. Typical applications are:

Environment	PROM		
	/14	/16	/26
Plant Surveys		+	+
NEI		+	+
Machine Testing		+	+
Community Noise	+		
Traffic Noise	+	+★	

NOTE: ★ Aircraft.

3. 2. 301/651 Metrologging System (Fig. 3)

The 301 Metrologger is designed for processing and storing sound level information. The 651 Metroreader is a desk analyzer with an internal printer. The 651 reader interrogates the 301's memories (similar to 306

---

* Canadian Standards Association Z 10-71, Type 2 meter.

TABLE 2

306 Metrologger - Program Modules

Replacement	Dynamic Range	Provision	Sample Rate	Levels
PROM /14	40 to 103 dBA	Test duration and SPL over a measurement range	4/sec	L_{eq}^{+} L max SPL
PROM /16	60 to 123 dBA	Test duration and SPL over a measurement range	4/sec	L_{eq}^{+} L max SPL
PROM /26	60 to 123 dBA	Test duration and SPL over a measurement range	4/sec	L OSHA* L max SPL
PROM /26-90	60 to 123 dBA	Test duration and SPL over a measurement range. The data below 90 dB will not be integrated into the L OSHA memory.	4/sec	L OSHA* L max SPL
PROM /26-85	60 to 123 dBA	Test duration and SPL over a measurement range. The data below 85 dB will not be integrated into the L OSHA memory.	4/sec	L OSHA* L max SPL

NOTE: + 3 dB exchange rate.
* 5 dB exchange rate.

Metrologger), calculates noise descriptors and simultaneously prints out all information on a built-in thermal printer, or XY plotters. Important data including time history profiles, amplitude distribution, histograms, computations of L_{eq}, L_{OSHA}, exposure coefficient at both 85 and 90 dBA criteria, and L_{10}, L_{90} (7).

A variety of PROM (Program Modules) in the program library make the Metrologger multi-functional (Table 3).

The 301/651 Metrologging System also meets the ANSI-S 1.4-1971, Type 2 requirement. The acoustical calibration can be carried out in the office. Typical applications are:

Environment	PROM				
	/14	/16	/26	/34	/36
Plant Surveys	+			+	+
NEI		+	+		
Machine Testing	+	+	+		
Community Noise				+	
Traffic Noise				+	+*

NOTE: * Aircraft.

3.3. Accuracy of Instruments

Two identical instruments with two different programs, the 301/14 Metrologger, and 301/34 Metrologger were exposed to landing noise for an equal length of time and with microphones very close to each other. The following results were obtained (Appendix 1 and 2):

TABLE 3

301 Metrologger - Program Modules

Replacement	Dynamic Range	Provision	Sample Rate	Levels
PROM /14	40 to 103 dBA	Time History for 8 hours	4/sec	L_{eq} +
PROM /16	60 to 123 dBA	Time History for 8 hours	4/sec	L_{eq} +
PROM /26	60 to 123 dBA	Time History for 8 hours	4/sec	L OSHA *
PROM /34	40 to 103 dBA	Sample Distribution up to 100 hours	4/sec	L_n L_{eq} + L OSHA * L OSHA (85) * L OSHA (90) *
PROM /36	60 to 123 dBA	Sample Distribution up to 100 hours	4/sec	L_n L_{eq} + L OSHA * L OSHA (85) * L OSHA (90) *

NOTE: + 3 dB exchange rate
* 5 dB exchange rate

MOL - MINISTRY OF LABOUR

	Metrologger	
	301/14	301/34
Time	00 : 55 : 26	00: 56 : 11
Samples	13305	13486
Time (estimated)	00 : 55 : 26.25	00 : 56 : 11.5
L_{eq}	72 dBA	71 dBA
L_{eq} (estimated)	71.37 dBA	-

The company claims that the instrument meets all ANSI S1.4-1971, Type 2 requirements. In the technical specifications for Digital Circuits the following is said:

Dynamic Range	64 dB
Resolution	1 dB
Conversion Accuracy	± 0.5 dB
Sample Rate 4 samples/sec	± 0.1%

From controlled L_{eq} measurements it became evident that the conversion accuracy is larger, 0.63 dB. However, the instrument still meets the Type 2 sound level meter requirements, and its accuracy is still good.

4. NOISE MEASUREMENT AND ASSESSMENT

Procedures to measure and evaluate noise exposure depend on the goal to be attained:

1) Assessment of the risk of hearing impairment (the present federal and provincial standards).
2) Assessment of the degree of interference to communications

essential for safety purposes.

3) Assessment of the risk of nervous fatigue, with due consideration to the work to be done.

4) Assessment of the community noise.

The Metrosonic measuring and analyzing instruments used meet all the requirements above.

4. 1. Hearing Impairment

The time history of a work-shop environment was observed (Fig. 4). The L_{eq} level was evaluated from the time history data, and results were compared:

$$67\ (\text{Cumul } L_{eq}) \approx 66.591\ (\overline{\text{SPL}} = L_{eq})$$

Also, the time history profile was plotted, 1 minute L_{eq} and 5 minutes L_{eq} versus time (Fig. 5). All possible combinations are as follows:

Time	:	Step	=	Minutes L_{eq}	Time	:	Step	=	Minutes L_{eq}	
60	:	1	=	60	60	:	10	=	6	
60	:	2	=	30	60	:	12	=	⑤	◄ OSHA
60	:	3	=	20	60	:	15	=	4	
60	:	4	=	15	60	:	20	=	3	
60	:	5	=	12	60	:	30	=	2	
60	:	6	=	10	60	:	60	=	①	◄ Engineering Control

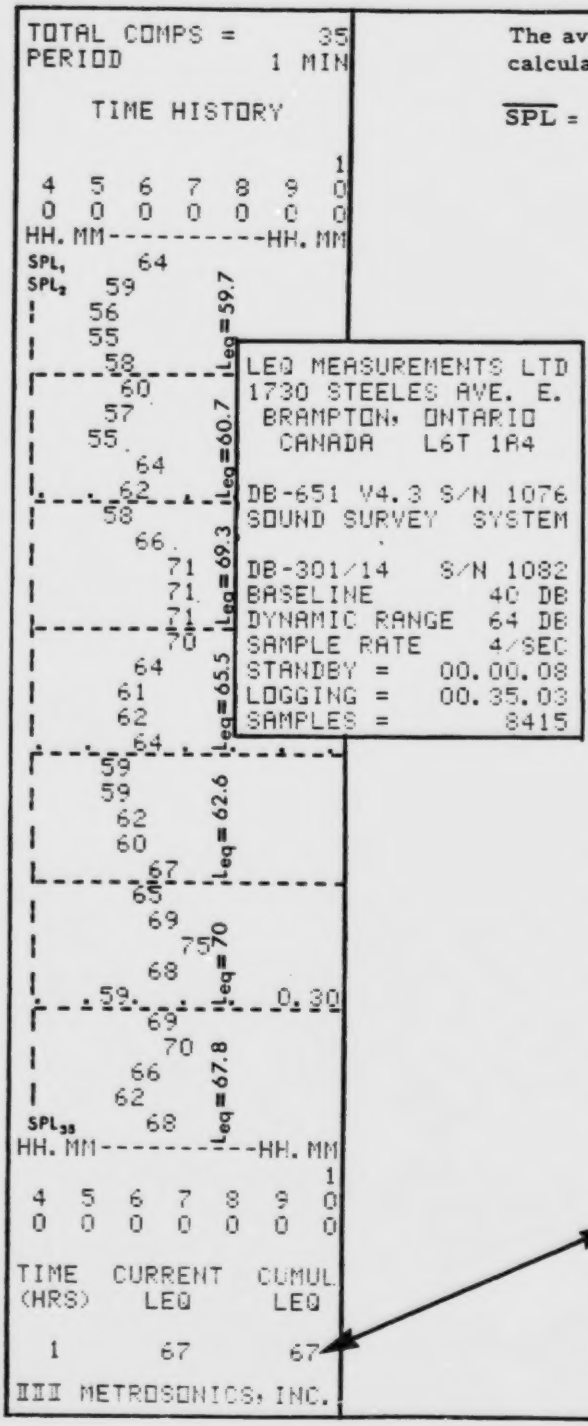
In general, everything depends on noise type:

1) long-term continuous noise, more than 30 minutes L_{eq};

2) short-term continuous noise, 10 to 30 minutes L_{eq};

3) intermittent equal-intensity noise, 5 to 10 minutes L_{eq};

4) intermittent variable-intensity noise 1 to 5 minutes L_{eq}; and



```
TOTAL COMPS =       35
PERIOD           1 MIN

    TIME HISTORY
```

```
LEQ MEASUREMENTS LTD
1730 STEELES AVE. E.
 BRAMPTON, ONTARIO
  CANADA    L6T 1A4

DB-651 V4.3 S/N 1076
SOUND SURVEY  SYSTEM

DB-301/14    S/N 1082
BASELINE        40 DB
DYNAMIC RANGE   64 DB
SAMPLE RATE     4/SEC
STANDBY =    00.00.08
LOGGING =    00.35.03
SAMPLES =        8415
```

```
TIME   CURRENT   CUMUL
(HRS)    LEQ      LEQ

 1       67       67

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```

The average $\overline{SPL}$ (sound pressure level) is calculated by the following equation:

$$\overline{SPL} = 10 \log \frac{1}{N} \left(\text{antilog} \frac{SPL_1}{10} + \text{antilog} \frac{SPL_2}{10} \right.$$
$$\left. ---- + \text{antilog} \frac{SPL_{35}}{10} \right)$$

PROGRAM FOR POCKET CALCULATOR HP-35

SPL_1		ENTER↑
-	10	÷
-	10	x^y
t_1	-	x
-	-	-
SPL_2	-	ENTER↑
-	10	÷
-	10	x^y
t_2	-	x, +
-	-	-
|	|	|
|	|	|
|	|	|
t_1	-	ENTER↑
t_2	-	+
|	|	|
|	|	|
|	|	|
t_{35}	-	+
-	-	÷ Log
-	-	-
-	10	x

Result 66.59099695 dBA

$$\boxed{\overline{SPL} = L_{eq}}$$

Fig. 4: Time history of work-shop environments at airport.

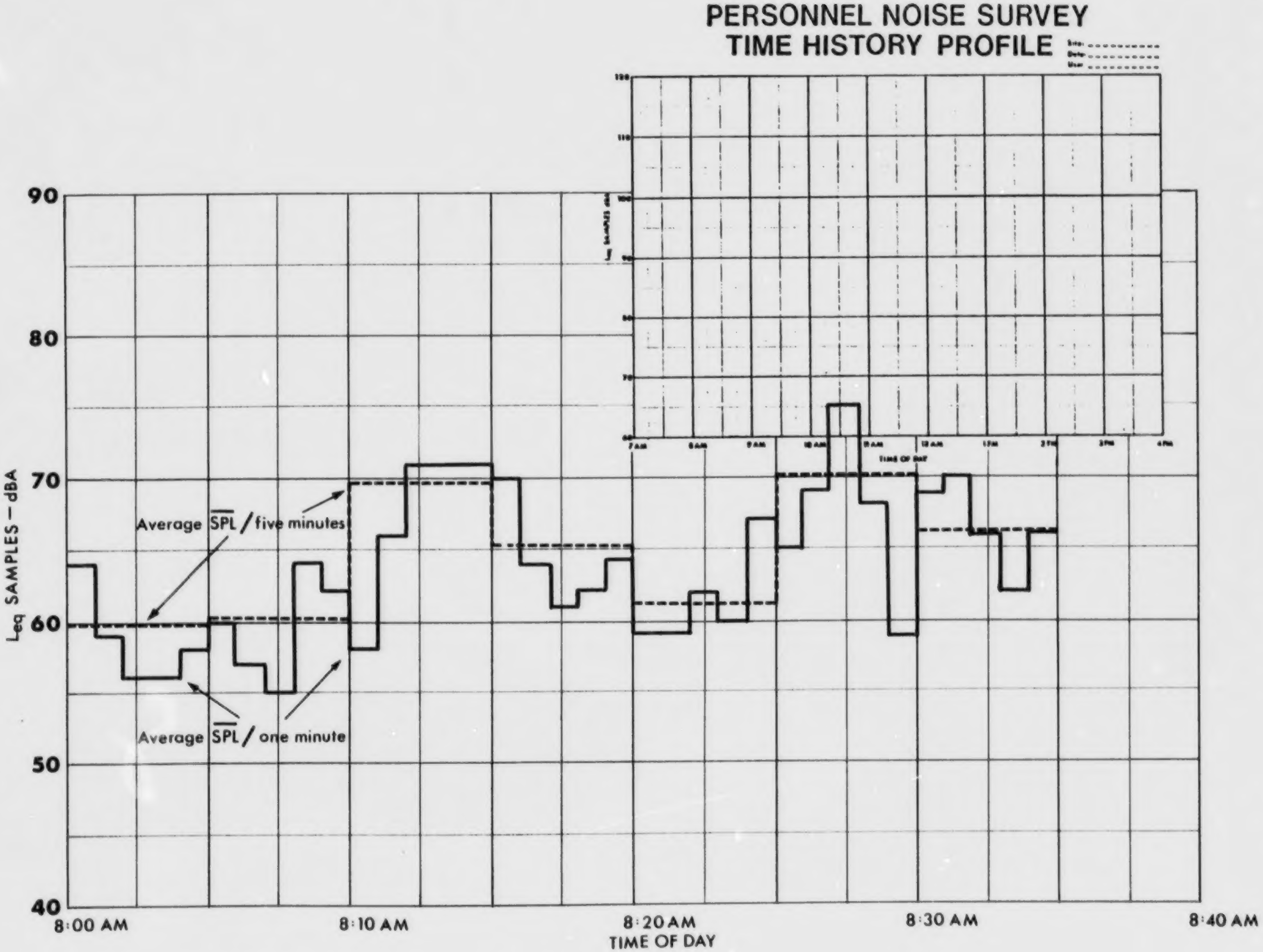


Fig. 5: Time history profile from Fig. 4.

5) impulse noise of less than 1 second will not register, which is the instrument's short-coming.

A simultaneous time history profile for an 8-hour work-day was made (Fig. 6). From the graph it is evident that the following data can be obtained:

1) machine noise;
2) real noise reduction using ear muffs;
3) percent of an ear muff's total discomfort (see: ear muff off). This would be the first time in qualitatively world literature that discomfort gets classified quantitavely. In the Elliot Lake Laboratory discomfort was classified qualitatively and for the first time such a feat was reported in writing;
4) calculating noise reduction versus time (8);
5) the various control methods may be combined in order to achieve a suitable reduction in noise levels, etc. NEI can easily and quickly be determined through a graphical method with the help of a nonogram (9).

4.2. Community Noise

In the community and in municipal planning, there are requirements for measuring the statistical distribution of noise levels in our environment. Criteria may require knowing that the sound level was excessive 10, 50 or 90% of the time, L_{10}, L_{50}, L_{90}. Consider the histogram of community noise derived by the 301/34 Metrologger (Fig. 7). Time in each amplitude band may be read in minutes or percent of total time. The cumulative distribution

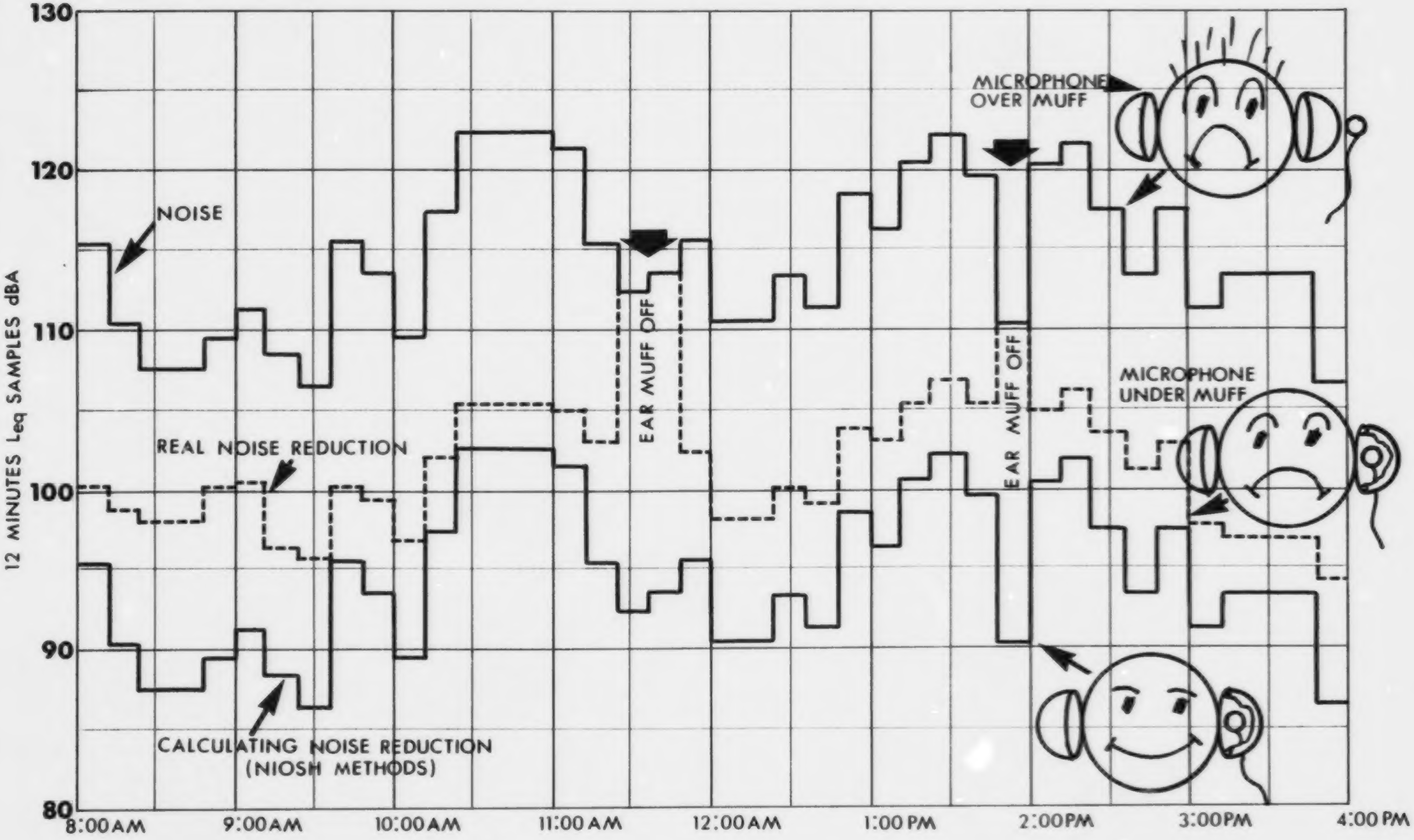
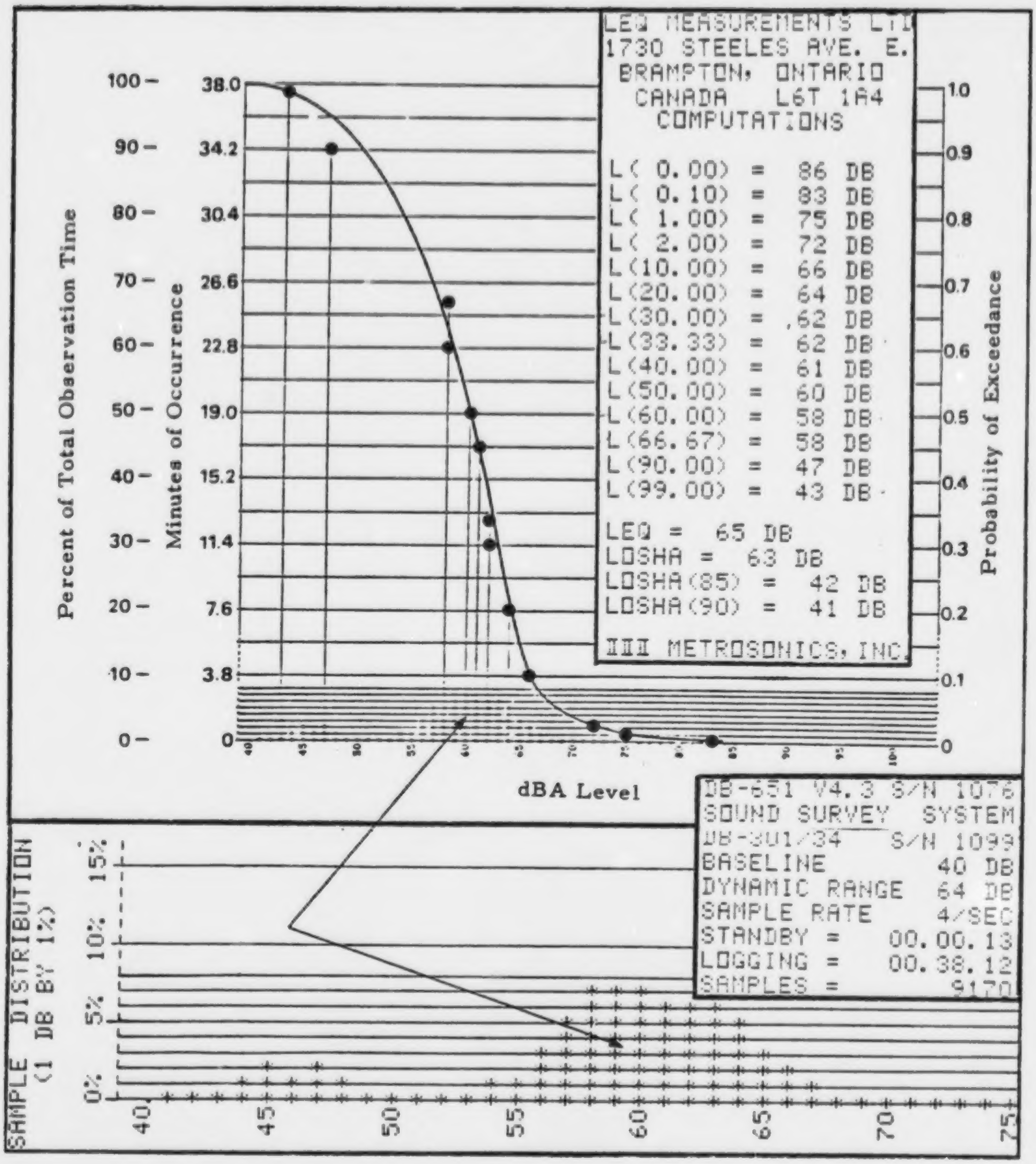


Fig. 6: Simulation time history profile in mine for an 8-hour work-day.



```
LEQ MEASUREMENTS LTI
1730 STEELES AVE. E.
 BRAMPTON, ONTARIO
  CANADA    L6T 1A4
   COMPUTATIONS

L( 0.00) =  86 DB
L( 0.10) =  83 DB
L( 1.00) =  75 DB
L( 2.00) =  72 DB
L(10.00) =  66 DB
L(20.00) =  64 DB
L(30.00) = ,62 DB
L(33.33) =  62 DB
L(40.00) =  61 DB
L(50.00) =  60 DB
L(60.00) =  58 DB
L(66.67) =  58 DB
L(90.00) =  47 DB
L(99.00) =  43 DB

LEQ =  65 DB
LOSHA =  63 DB
LOSHA(85) =  42 DB
LOSHA(90) =  41 DB

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```

```
DB-651 V4.3 S/N 1076
SOUND SURVEY  SYSTEM
DB-301/34    S/N 1099
BASELINE        40 DB
DYNAMIC RANGE   64 DB
SAMPLE RATE     4/SEC
STANDBY =    00.00.13
LOGGING =    00.38.12
SAMPLES =        9170
```

Fig. 7: Histogram of community noise. The histogram shows the profile of community noise during 38.12 minutes.

curve (probability of exceeding) indicates the levels that exceeded any percentage of time. For example: $L_{10} = 66$ dBA, $L_{50} = 60$ dBA, and $L_{90} = 47$ dBA HUD (housing-urban-development) requirements for describing exposure on new construction sites using criteria for Traffic Noise Index (TNI) and Noise Pollution Level (L_{NP}) (10).

$$\begin{aligned} TNI &= 4(L_{10} - L_{90}) + (L_{90} - 30) \qquad \text{Eq. 2} \\ &= 4(66 - 47) + (47 - 30) \\ &= 93 \end{aligned}$$

$$\begin{aligned} LNP &= L_{50} + d + d^2/60 \qquad \text{Eq. 3} \\ &= 60 + 19 + 19^2/60 \\ &= 85 \text{ dBA} \end{aligned}$$

$$\text{where } d = (L_{10} - L_{90})$$

To determine community noise, it is necessary to have complete time histories for statistical analysis.

5. DISCUSSION

1. With the introduction of newer, larger and more powerful machines, owing to the growth of mining exploration, came a significant increase in the number and power of noise sources over the past two decades.
2. The question: how much degradation of pneumatic machine noise is there and by how much is LHD noise increased, is always posed. In the same way, we don't have definitive data regarding the increase of noise in mines (or the decrease of noise, if proper protective measurements have been taken). Current existing data are very scant and inadequate to

produce results with any degree of confidence. The target noise levels vary over the time periods according to a probability distribution (Fig. 8).

3. Canada pays millions and will be paying out millions of dollars more for employees' job-related hearing losses. Safety rules have been disregarded and disciplinary action lacking.
4. More needs to be done to protect miners' hearing and to reduce hearing loss claims.
5. The hazardous noise areas identified in some surveys were not sufficiently defined.
6. To survey all problems above with higher accuracy, the Elliot Lake Laboratory made the suggestion to Metrosonic Inc. to connect the 301/651 Metrologging System to a computer in a way most beneficial to Canadian mines (Fig. 3). A positive answer was received from Metrosonics Inc.
7. The 306 Metrologger is excellent for short measurements of NEI and for testing ear muff efficiency.

6. CONCLUSION

New instruments are part of the procedure to obtain the full information required for the establishment of control programs for the mining environment:

- noise measurement and assessment;
- identification of risk areas;
- noise control in the working environment; and
- control of protective equipment and reduction of exposure time.

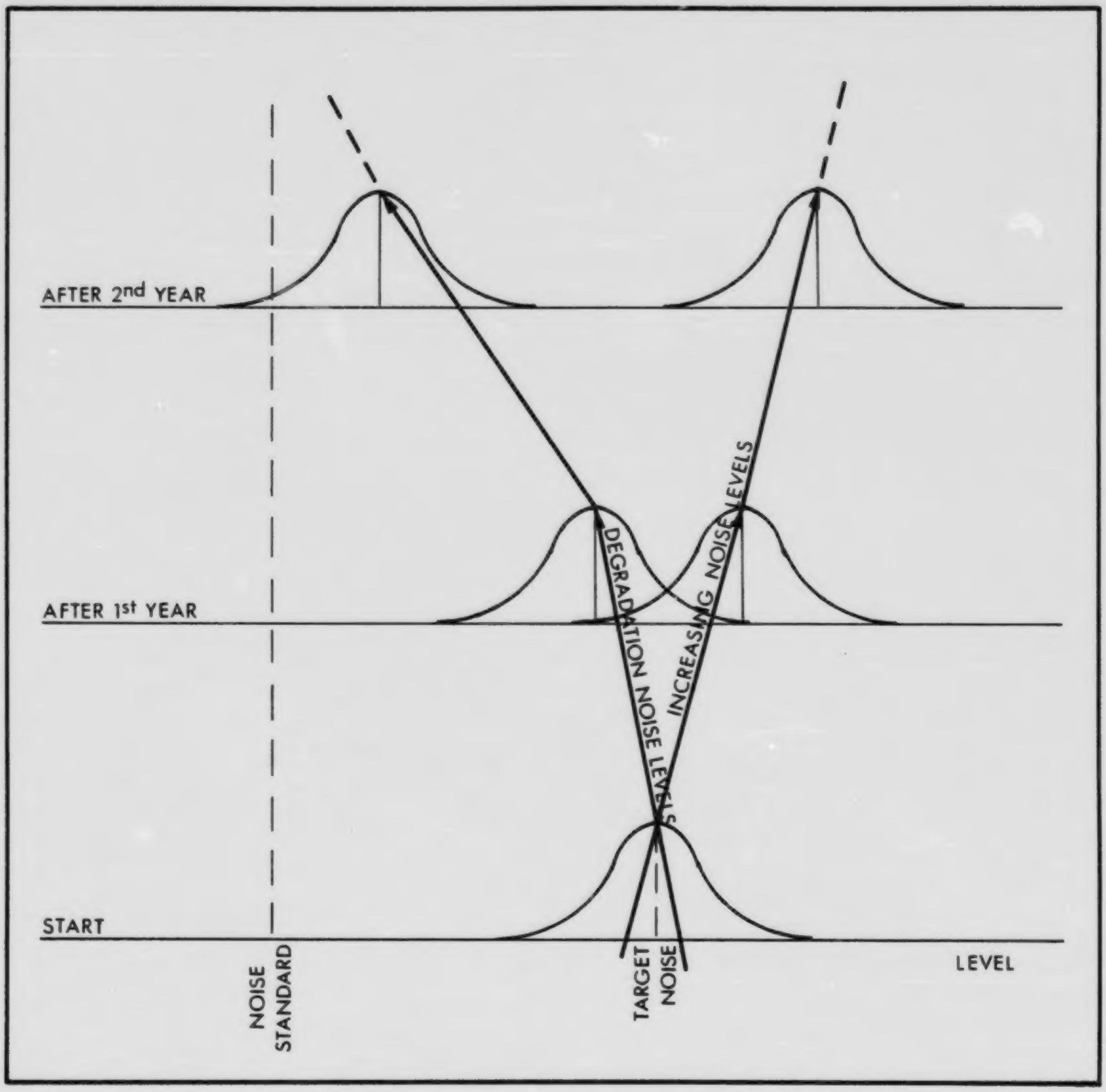
AFTER 2nd YEAR
AFTER 1st YEAR
START
NOISE STANDARD
TARGET NOISE
LEVEL
DEGRADATION NOISE LEVELS
INCREASING NOISE LEVELS

Fig. 8: The target noise levels over the time periods.

These instruments cannot safisfy the requirement to register impulse numbers or impacts per work-day because instruments are not constructed in such a way.

The 301/651 Metrologging system is a significant advance in noise monitoring instrumentation. Proposed systems go so far as to enable a computer to write a technical printout with all necessary results. Of course, the printout can be obtained immediately after measurements have been taken.

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Toronto International Airport

```
LEQ MEASUREMENTS LTD
1730 STEELES AVE. E.
 BRAMPTON, ONTARIO
  CANADA   L6T 1A4

DB-651 V4.3 S/N 1076
SOUND SURVEY  SYSTEM

DB-301/14   S/N 1082
BASELINE        40 DB
DYNAMIC RANGE   64 DB
SAMPLE RATE     4/SEC
STANDBY =    00.17.22
LOGGING =    00.55.26
SAMPLES =       13305
SITE
    -----------------
DATE
    -----------------
USER
    -----------------
TOTAL COMPS =      55
PERIOD          1 MIN

     TIME HISTORY

                    1
 4  5  6  7  8  9  0
 0  0  0  0  0  0  0
HH.MM---------HH.MM
        67
        67
    55
      62
      62
   53
   52
     59
     58
 .  . 61  .  .   Leq = 62.19
     57              dBA
        67
     59
    56
             84
        69
    55
   52
           77   Leq = 76.20
 .  .  .  . 80   .  . dBA
```

```
     62
          79
 49
   56
44
  53
 47
  50                 Leq = 69.14
 47                      dBA
.49.  .  .  .   0.30
 49
 47
   56
   55
  53
 48
 47
46                   Leq = 51.06
46                       dBA
46 .  .  .  .  .  .
  53
   56
         76
          77
     60
  50
  50
    59
   56                Leq = 69.69
. 52  .  .  .  .  .      dBA
          79
  53
     62
          78         Leq = 71.60
  50                     dBA
HH.MM----------HH.MM
                   1
 4  5  6  7  8  9  0
 0  0  0  0  0  0  0

TIME   CURRENT   CUMUL
(HRS)    LEQ      LEQ

 1        72       72

III METROSONICS, INC.
                     Leq = 71.37
                         dBA
```

Toronto International Airport

```
LEQ MEASUREMENTS LTD
1730 STEELES AVE. E.
 BRAMPTON, ONTARIO
  CANADA    L6T 1A4

DB-651 V4.3 S/N 1076
SOUND SURVEY  SYSTEM

DB-301/34    S/N 1079
BASELINE       40 DB
DYNAMIC RANGE  64 DB
SAMPLE RATE    4/SEC
STANDBY =   00.13.56
LOGGING =   00.56.11
SAMPLES =      13486
SITE
----------------
DATE
----------------
USER
----------------
```

```
     COMPUTATIONS

L( 0.00)  =   93 DB
L( 0.10)  =   91 DB
L( 1.00)  =   86 DB
L( 2.00)  =   83 DB
L(10.00)  =   65 DB
L(20.00)  =   59 DB
L(30.00)  =   55 DB
L(33.33)  =   54 DB
L(40.00)  =   52 DB
L(50.00)  =   50 DB
L(60.00)  =   49 DB
L(66.67)  =   48 DB
L(90.00)  =   44 DB
L(99.00)  =   40 DB

LEQ =    71 DB
LOSHA =   64 DB
LOSHA(85)  =   58 DB
LOSHA(90)  =   51 DB

METROSONICS, INC.
```

```
SAMPLE  DISTRIBUTION
  (1 DB BY 1%)

  0%   5%   10%  15%
  ----------------
40**
  **
  **
  ***
  ****
45*****
  ******
  *******
  *******
  *******
50******
  ******
  *****
  ****
  ****
55***
  ***
  **
  **
  **
60**
  **
  **
  *
  *
65*
  *
  *
  *
  *
70*
  *
  *
  *
  *
75*
  *
  *
  *
  *
80*
  *
  *
  *
  *
85*
  *
  *
  *
  *
90*
```

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VOL. I Report II

78-62 M.U. Savich

A significant advance in noise

monitoring instrumentation

1978

MISE AU POINT D'UN CASQUE DE SURVEILLANCE DU BRUIT

par

M. Savich*

RÉSUMÉ

Résumé : Les essais initiaux au laboratoire et dans les mines du casque de surveillance du bruit sont présentés. La précision des mesures de l'exposition au bruit était supérieure aux normes.

L'un des problèmes dans la mesure de l'exposition au bruit dans les mines canadiennes réside dans le fait que les instruments de mesure sont placés en permanence près de l'oreille de l'opérateur. Les chercheurs du Laboratoire d'Elliot Lake de CANMET, EMR, contribuent à la résolution du problème suivant : mesurer l'exposition au bruit à l'aide d'un casque de surveillance du bruit par une méthode simple qui répond aux normes.

Le dosimètre GenRad 1944 a été choisi pour le casque et un dosimètre B et K, type 4425, a été utilisé comme témoin.

L'essai sur le terrain a confirmé l'exactitude de l'essai au laboratoire (± 1,5 dB plus précis que l'exigent les normes).

Mots-clés : Dosimètre de bruit, casque de surveillance du bruit, exposition au bruit, laboratoire, mines.

* Chercheur, Laboratoire d'Elliot Lake, Laboratoires de recherche minière, Centre canadien de la technologie des minéraux et de l'énergie, ministère de l'Énergie, des Mines et des Ressources, Elliot Lake (Ontario)

Les systèmes mis au point pour l'analyse de l'exposition au bruit devraient pouvoir être utilisés dans d'autres activités, aussi bien dans le secteur public que dans le secteur privé.

DEVELOPMENT OF A NOISE MONITOR HAT

by

M. Savich*

ABSTRACT

Summary: Initial laboratory and mine tests of the Noise Monitor Hat ability are presented. The accuracy of measuring noise exposure was better than the requirements of the Standards.

One of the problems in measuring the noise exposure in Canadian Mines is that the measuring instruments are permanently located at the operator's ear. The Elliot Lake Laboratory, CANMET, E. M. R., is to contribute to the solution of this problem: to measure the noise exposure with the Noise Monitor Hat by a simple method which will meet the criteria.

The noise dosimeter, GenRad 1944, was chosen to be built into a helmet (hat) and a noise dosimeter, B and K, type 4425 was used as a control unit.

The accuracy of the field test has confirmed the correctness of the laboratory test (± 1. 5 dB better than the requirements of the Standards).

The developed systems for Noise Exposure analysis are expected to have application to other Federal and non-Federal activities.

Key words: Noise Dosimeter, Noise Monitor Hat, Noise Exposure, Laboratory, Mines.

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1. INTRODUCTION

Rapid development has taken place during the last decade in measuring the noise exposure of industrial workers in Canadian Mines. As a result of the promulgation of occupational noise exposure regulations by the OSHA* there are a number of commercial noise dosimeters on the market today that provide a measure of noise integrated over a time interval. Criteria for occupational noise exposure in North America and Europe can be referred to two sources: in North America the OSHA and in Europe ISO** (Fig. 1). In both cases, the criteria are based on measurements of the equivalent continuous noise level (L_{eq}): 5 dB per double time used by the

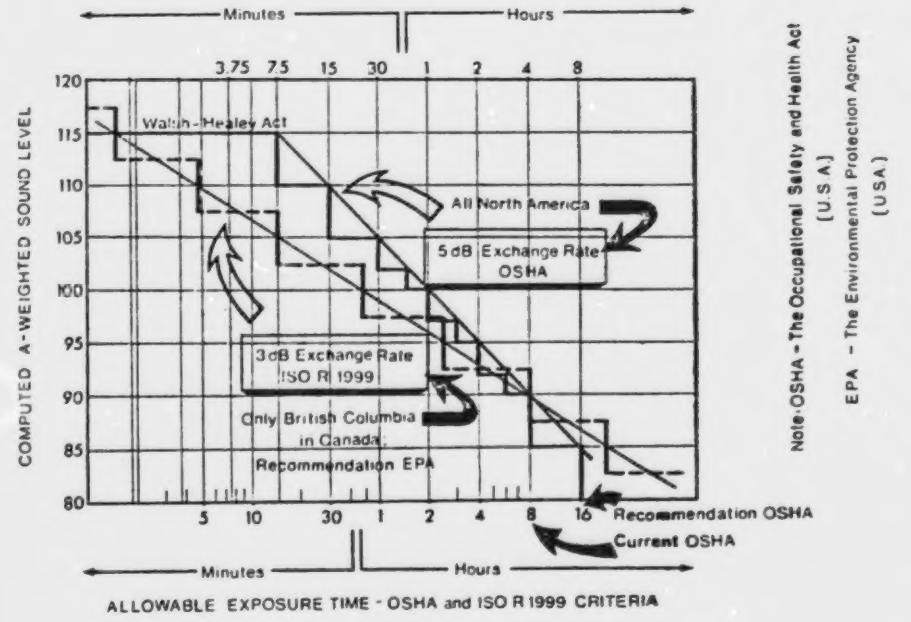


Fig. 1: The relationship between sound level and duration for the OSHA and ISO R 1999.

---

* The Occupational Safety and Health Act (U.S.A.).

** The International Organization for Standardization.

OSHA, and 3 dB per double time recommended by the ISO (recommended by the EPA).

Tests have shown that a wide variation of performance exists among various noise exposure meters (1 to 10).

The Elliot Lake Laboratory, CANMET, E.M.R., is to contribute to the solution of this problem: to measure the noise exposure with the Noise Monitor Hat by a simple method which will meet the criteria (11).

1.1. Noise Dosimeter Design

The noise dosimeter design is based on the mathematical function below (ANSI S1.25-1978):

$$D = (100/T_c) \int_0^T \text{antilog}\,[(L - L_c)/q]\,dt, \qquad \text{Eq. 1}$$

where: D = percentage criterion exposure;

T_c = criterion sound duration = 8 hr;

T = measurement duration in hours;

t = time in hours;

L = slow, A-weighted sound level, a function of time, when the sound level is greater than or equal to L_t, or equals $-\infty$, when the A-weighted sound level is less than L_t;

L_t = threshold sound level specified by the manufacturer;

L_c = criterion sound level specified by the manufacturer; and

q = parameter that determines the exchange rate

q = 10 for a 3-dB exchange rate

q = 5/log 2 for a 5-dB exchange rate.

There are two types of dosimeter (Fig. 2). The output signal goes to an integrator circuit which produces a DC voltage which doubles for each increase of 5 dB or 3 dB in the noise level at the microphone input. In type A, the signal is fed to an electrochemical memory cell and causes plating on the electrodes. The amount of plating is then measured. In the second type, the signal from the integrator circuit is converted to pulses that are counted and later read out as an exposure index. The noise dosimeters comply with ANSI S1.4.1971 for Type 2 Sound Level Meter.

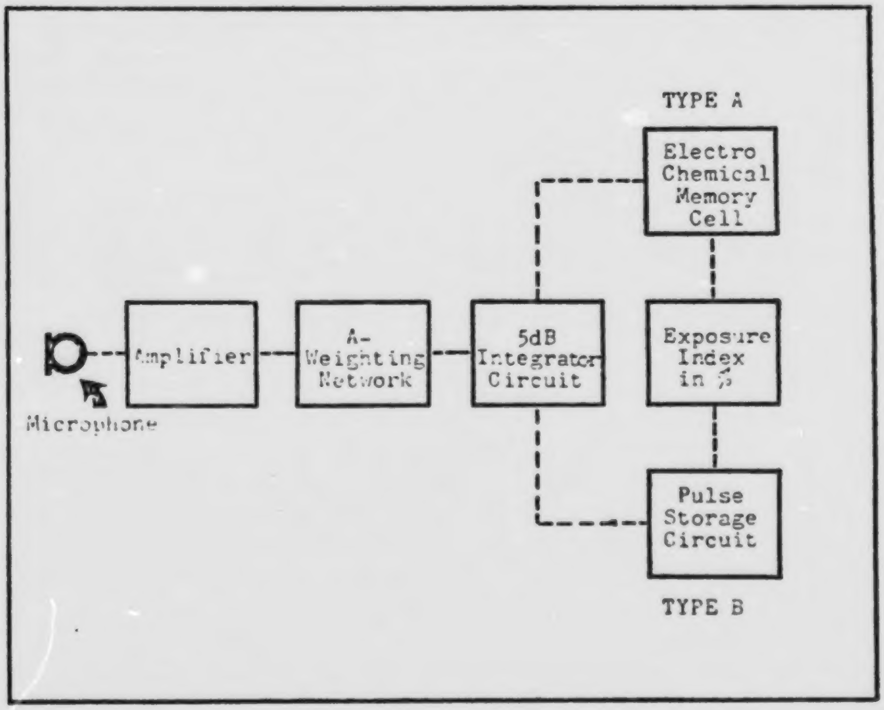

TYPE A
Electro Chemical Memory Cell
Microphone
Amplifier
A-Weighting Network
5dB Integrator Circuit
Exposure Index in %
Pulse Storage Circuit
TYPE B

Fig. 2: Two types of noise dosimeters.

1.2. The Effect of dBA Variation on Percentage Reading

The range of tolerance limits for a Type 2 Sound Level Meter is from plus 3.5 dB or minus 4.0 dB in the low frequencies, to plus or minus

6.5 dBA at 8000 Hz. The sound level tolerance limits are widest at 4000 to 8000 Hz, and the dosimeter noise exposure percentage reading is greatly influenced by these limits, especially at the higher frequencies (Table 1).

TABLE 1

The Effect of Instrument Tolerance Limits on Noise Exposure Readings

Sound Level Meter ANSI S1.4-1971, Type 2		Dosimeter Reading when Expecting 100% Exposure Based on OSHA Criteria
Frequency Hz	A-Weighting dB	
31.5	+3.5, -4.0	162.4, 57.4
63	+3.0, -3.0	151.6, 66.0
125	+2.5, -2.5	141.4, 70.7
250	+2.5, -2.5	141.4, 70.7
500	+2.0, -2.0	132.0, 75.8
1000	+2.0, -2.0	132.0, 75.8
2000	+3.0, -3.0	151.6, 66.0
4000	+5.5, -4.5	214.4, 53.6
8000	+6.5, -6.5	246.2, 40.6

In light of the foregoing, an arbitrary decision was made to use a ± 2 dBA limit on overall noise dosimeter accuracy (12).

2. SELECTION OF NOISE DOSIMETERS

In the Elliot Lake Laboratory several dosimeters were investigated and two dosimeters were chosen as the best: GenRad 1944 and Brüel and Kjaer 4425. The MSHA* also accepted these two dosimeters (13).

---

* The Mine Safety and Health Administration.

The NIOSH* also tested nine dosimeter units (10). The dosimeter units tested were subjected to acoustical, electrical and environmental evaluations in accordance with a proposed NIOSH certification program for such devices. In Fig. 3, the units are labelled pass/fail (P/F) for each of the tests performed. No single unit passed all of the tests. From the results of the tests, the negative skewness was plotted. Skewness usually arises from natural causes. Thus, the frequency curve, caused by selection, is skewed to the left.

The standard deviation of this negative skewness is ~17% (14). Again, the GenRad 1954 (new type) and Brüel and Kjaer 4425 were chosen in the range from 70% to 95% of the tests passed or in the range of 68. 3% of the total. Both of them showed that our selection was good.

The aims of the noise monitor hat studies are outlined in Fig. 4 under two general headings:

1) Laboratory tests in Elliot Lake Laboratory; and
2) Underground mine tests.

Results obtained under the two general headings were computed and compared. Four independent surveyors carried out the tests to eliminate biased personal opinions or errors.

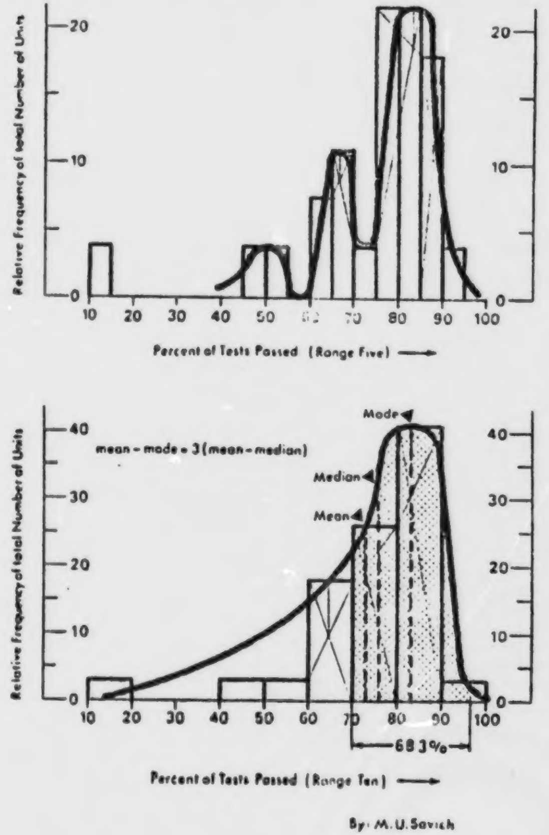
The author carried out the tests in ordinary spaces such as Laboratory or office areas with accuracies adequate for many practical problems.

---

* The National Institute for Occupational Safety and Health.

Personal Noise Docimeter	Unit	Frequency Response	Calibrator Accuracy	Cut/off Level	Shifting Level	Rise and Decay Time	Exponential Formula	Fold/over Test	Integration Accuracy	Crest Factor/Square Law	Battery Life	Battery Indicator	Dose Storage	Temperature Sensitivity	Magnetic Field Sensitivity	115 dB (A, Slow) Latch	Atmospheric Pressure Evaluation	Drop	Cable	Temperature Endurance	Percent of Tests Passed	Average Percent	Order of Performance
B&K 4425	1	P	F	P	F	P	P	P	P	P	P	P	-	F	P	F	-	-	-	-	78.6	74	6
(TypeB)	2	P	P	F	F	P	P	P	P	P	F	P	-	F	P	F	-	F	F	P	64.7		
	3	F	P	P	P	P	P	P	[illegible]	P	F	P	-	F	P	F	-	-	-	-	74.6		
Bendix ADS-3000	1	F	F	F	P	F	F	P	P	P	P	P	P	P	P	F	-	-	-	-	66.7	697	7
(TypeB)	2	F	F	F	P	P	F	P	P	P	P	P	P	F	P	F	-	F	P	F	71.1		
	3	F	[illegible]	P	P	P	F	P	P	P	P	P	P	F	P	F	P	-	-	-	[illegible]		
Columbia SPL-105	1	P	P	P	F	F	F	P	P	P	P	P	-	F	P	F	-	-	-	-	64.2	689	8
(TypeB)	2	P	P	P	P	F	F	P	P	P	P	P	-	P	P	F	-	P	P	P	82.4		
	3	F	P	P	F	F	F	P	P	P	P	P	-	F	P	F	F	-	-	-	60.0		
Dupont D-376	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P	P	89.5	854	1
(TypeA)	2	P	P	P	P	P	F	P	P	P	F	F	P	P	P	P	-	-	-	-	80.0		
	3	P	P	F	P	P	P	P	P	P	P	F	P	F	P	P	-	-	-	-	86.7		
Edmont-Wilson 60-520	1	P	P	P	F	F	P	P	P	P	P	F	P	P	P	F	-	P	P	P	77.8	818	3
(TypeB)	2	F	P	P	F	F	P	P	P	P	F	P	P	P	P	F	-	-	-	-	80.0		
	3	P	P	P	F	F	P	P	P	P	P	P	P	P	P	P	P	-	-	-	87.5		
GenRad 1954	1	P	P	P	P	P	P	P	P	P	P	P	P	F	P	F	-	-	-	-	86.7	84	2
(TypeB)	2	P	P	P	P	P	P	P	P	P	P	P	P	F	P	F	-	F	P	F	77.7		
	3	P	P	P	P	P	P	P	P	P	P	P	P	F	P	F	P	-	-	-	87.5		
Quest M-7	1	P	F	P	P	P	F	P	P	P	F	P	P	F	P	F	P	-	-	-	81.3	797	4
(TypeB)	2	F	P	P	P	P	F	P	P	P	P	P	[illegible]	F	P	F	-	F	F	P	77.7		
	3	P	F	P	P	P	F	P	P	P	P	P	P	F	P	F	-	-	-	-	80.0		
Quest M-6	1	P	P	P	P	F	P	P	P	P	P	P	P	F	P	P	-	-	-	-	66.7	78	5
(TypeB)	2	P	P	P	F	F	P	P	P	P	P	F	P	F	P	P	P	-	-	-	75.0		
	3	P	F	F	P	F	P	P	P	P	F	F	P	F	P	P	-	P	P	P	72.2		
Tracoustics ND-100	1	F	F	P	F	*	F	P	*	*	*	-	-	*	*	*	-	-	-	-	15.4	388	9
(TypeB)	2	P	F	P	F	F	F	P	P	F	P	-	-	F	P	P	P	*	*	*	47.1		
	3	P	F	P	F	F	F	P	P	F	P	-	-	F	P	P	-	-	-	-	53.8		

By: R.L.Fortner and N.Blaskovich, Jr.



By: M.U.Savich

NOTE: (P) Pass.
(F) Fail.

(*) Failed to function during testing program.
(-) Test not performed on this unit.

Fig. 3: Personal noise dosimeters evaluated in NIOSH testing.

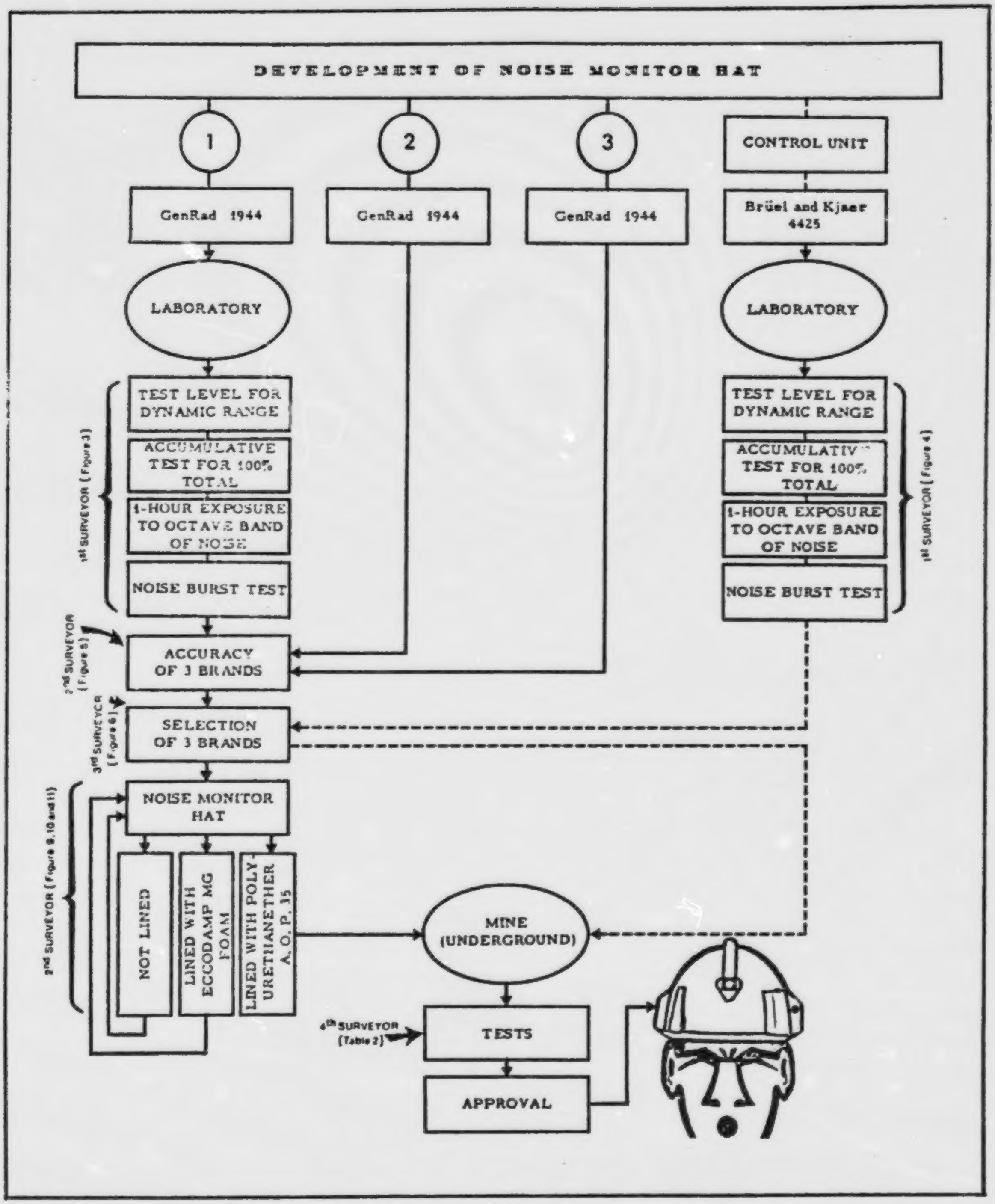

DEVELOPMENT OF NOISE MONITOR HAT
1
2
3
CONTROL UNIT
GenRad 1944
GenRad 1944
GenRad 1944
Brüel and Kjaer 4425
LABORATORY
LABORATORY
TEST LEVEL FOR DYNAMIC RANGE
ACCUMULATIVE TEST FOR 100% TOTAL
1-HOUR EXPOSURE TO OCTAVE BAND OF NOISE
NOISE BURST TEST
1st SURVEYOR (Figure 3)
TEST LEVEL FOR DYNAMIC RANGE
ACCUMULATIVE TEST FOR 100% TOTAL
1-HOUR EXPOSURE TO OCTAVE BAND OF NOISE
NOISE BURST TEST
1st SURVEYOR (Figure 4)
2nd SURVEYOR (Figure 5)
ACCURACY OF 3 BRANDS
3rd SURVEYOR (Figure 6)
SELECTION OF 3 BRANDS
NOISE MONITOR HAT
2nd SURVEYOR (Figure 9,10 and 11)
NOT LINED
LINED WITH ECCODAMP MG FOAM
LINED WITH POLY-URETHANETHER A. O. P. 35
MINE (UNDERGROUND)
4th SURVEYOR (Table 2)
TESTS
APPROVAL

Fig. 4: Flow sheet diagram of noise monitor hat development.

3. DEVELOPMENT OF THE NOISE MONITOR HAT

The noise dosimeter GenRad 1944 was chosen to be built-into a helmet (hat), and the noise dosimeter, B and K, type 4425 was used as a control unit. Both instruments were tested in the laboratory and underground mines, before final designs were made.

Tests were carried out in the "average living room" or a "semi-reverberant field", because of economic reasons. High quality anechoic or reverberant chambers are too expensive (15). Also, we had the same semireverberant field in the mines.

3. 1. Laboratory Test

A comparison was made of the values of the Noise Exposure Index (NEI) measured by noise dosimeters. The noise dosimeters were previously calibrated. Sine-wave signals and pink noise output wave forms were used for response measurements. In all cases, the level and time were adjusted to give a noise exposure index of 1. 0. In order for the noise dosimeters to achieve the maximum possible accuracy, the tolerance of the comparison should be better than the tolerances specified for a Sound Level Meter, Type 2. For this reason, the dosimeter microphone of the sound level meter, B and K, type 2209, confirms with ANSI S1. 4-1971 Type 1.

3. 1. 1. Performance Data for the Noise Dosimeters: GenRad 1944, and Brüel and Kjaer 4425

Four basic tests were carried out on two noise dosimeters: GenRad 1944, and Brüel and Kjaer 4425 (Fig. 5 and 6):

1) Test levels for dynamic range, 85 or 90 dBA to 115 dBA;

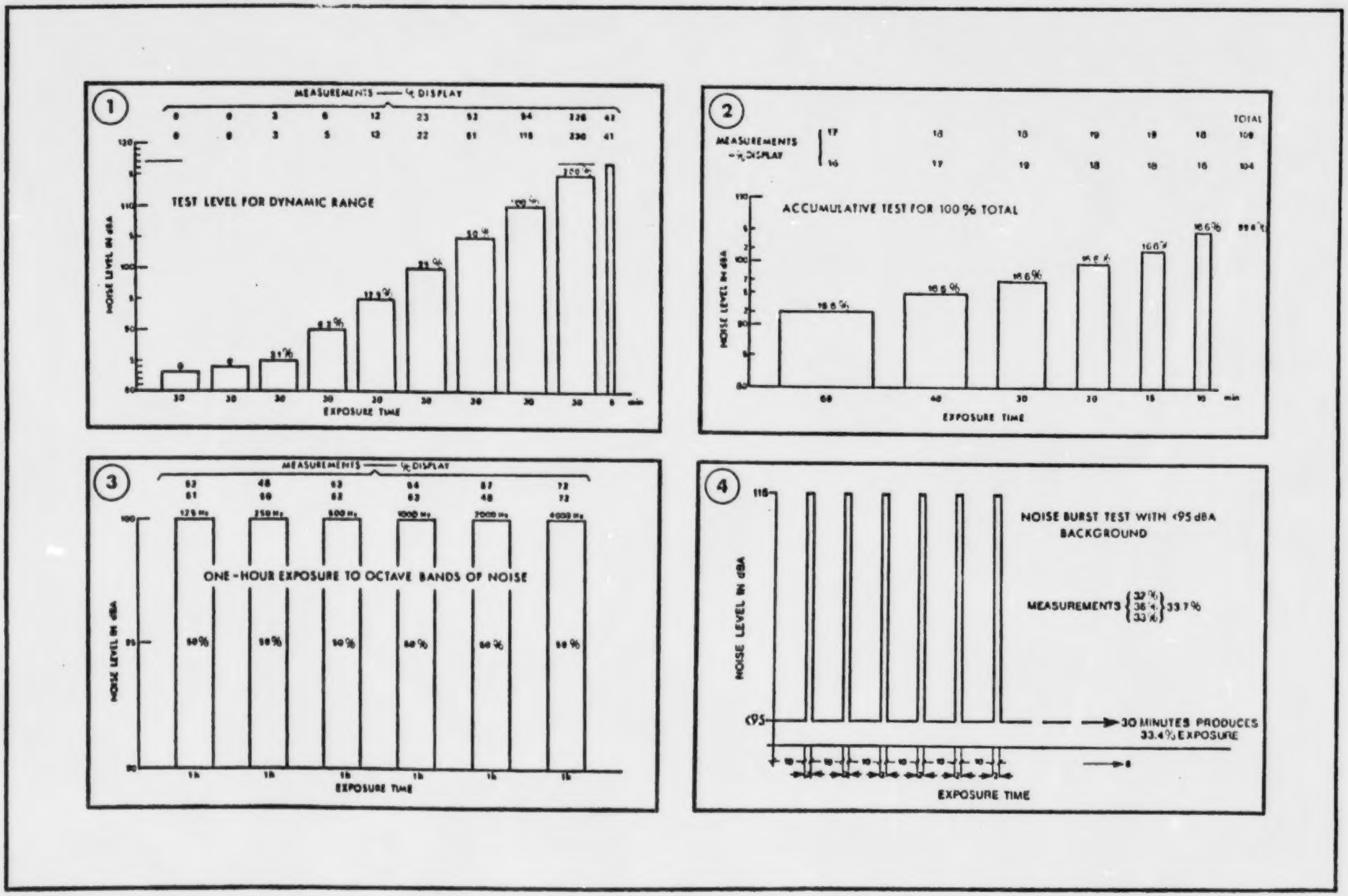


Fig. 5: Performance data for the GenRad 1944 Noise Dosimeter.

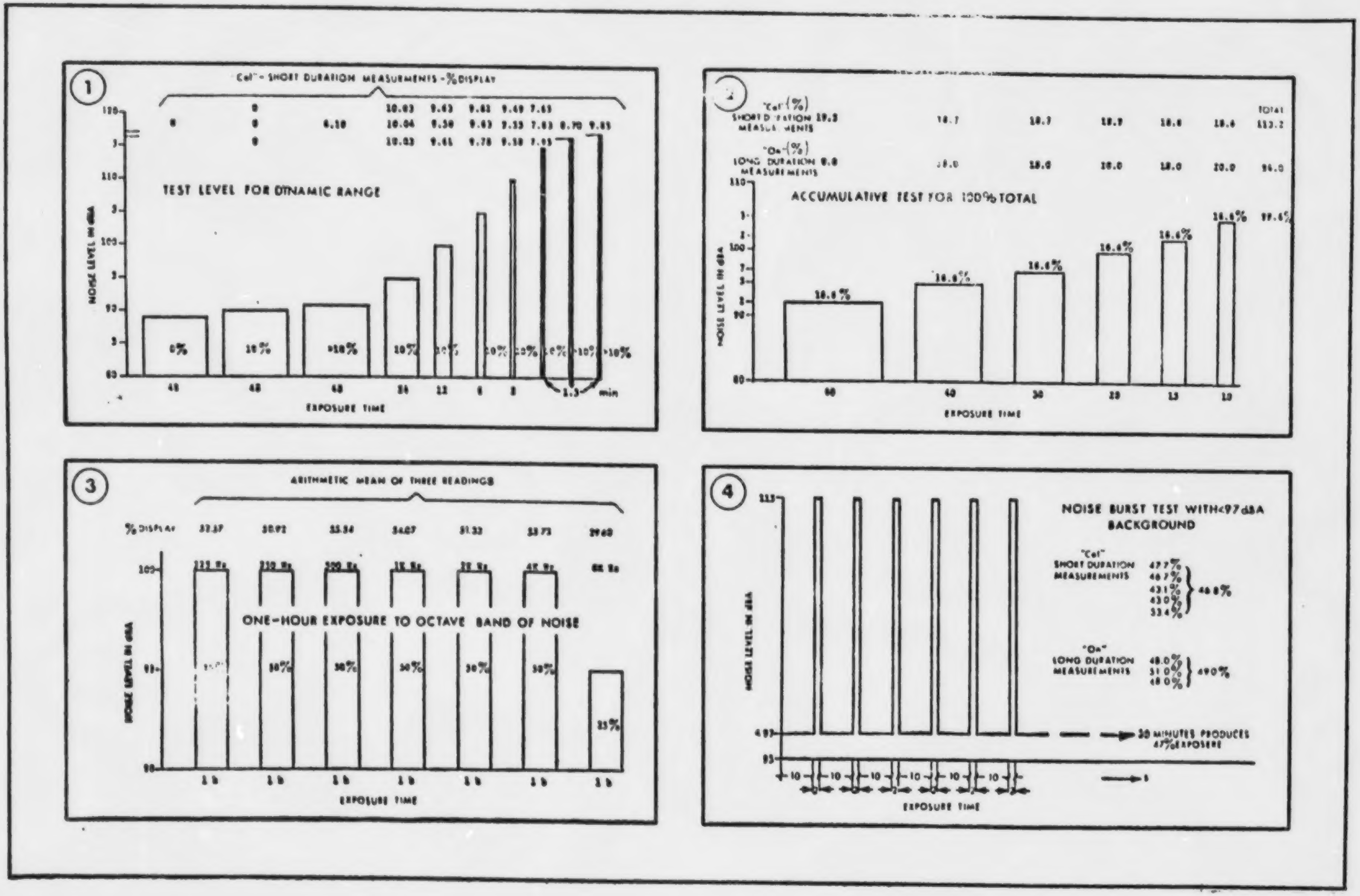


Fig. 6: Performance data for the Brüel and Kjaer 4425 noise dosimeter.

2) The accumulative test for 100 percent total. The sound level was controlled in each interval to correspond to 16.6 percent exposure;
3) The one-hour exposure test at 100 dB octave band noise from 125 Hz to 4 kHz (8 kHz); and
4) The noise burst test, to investigate the effects of intermittent noise peaks. The background level was less than 95 dBA with 115 dBA pulses of 2 seconds duration separated by intervals of ten seconds.

All readings were within tolerance and both dosimeters comply with ANSI S1.4-1971 for Type 2 Sound Level Meter. Examination of the test data from the GenRad 1944 dosimeter showed the 4000 Hz band to have the greatest error (Fig. 5 - 3).

3.1.2. Accuracy and Selection of the GenRad 1944 Dosimeters

Three GenRad 1944 dosimeters were evaluated to meet an overall tolerance of ± 2 dBA. Measurements of directional sounds were made at four orientations of the microphone. The results were averaged.

The dark area in Fig. 7 shows the exposure results by dosimeters when exposed to various noise levels. All three instruments confirmed noise exposures in the range of tolerance limits.

Almost the same test was repeated with a new surveyor and new displacing objects in the room. Three GenRad 1944 dosimeters were compared with the B and K Type 4425 dosimeter. The selection was accomplished with the following results. One of the three GenRad 1944 dosimeters with the best results in the test, was selected to be built into a hard hat (helmet) (Fig. 8). The other two dosimeters were also selected

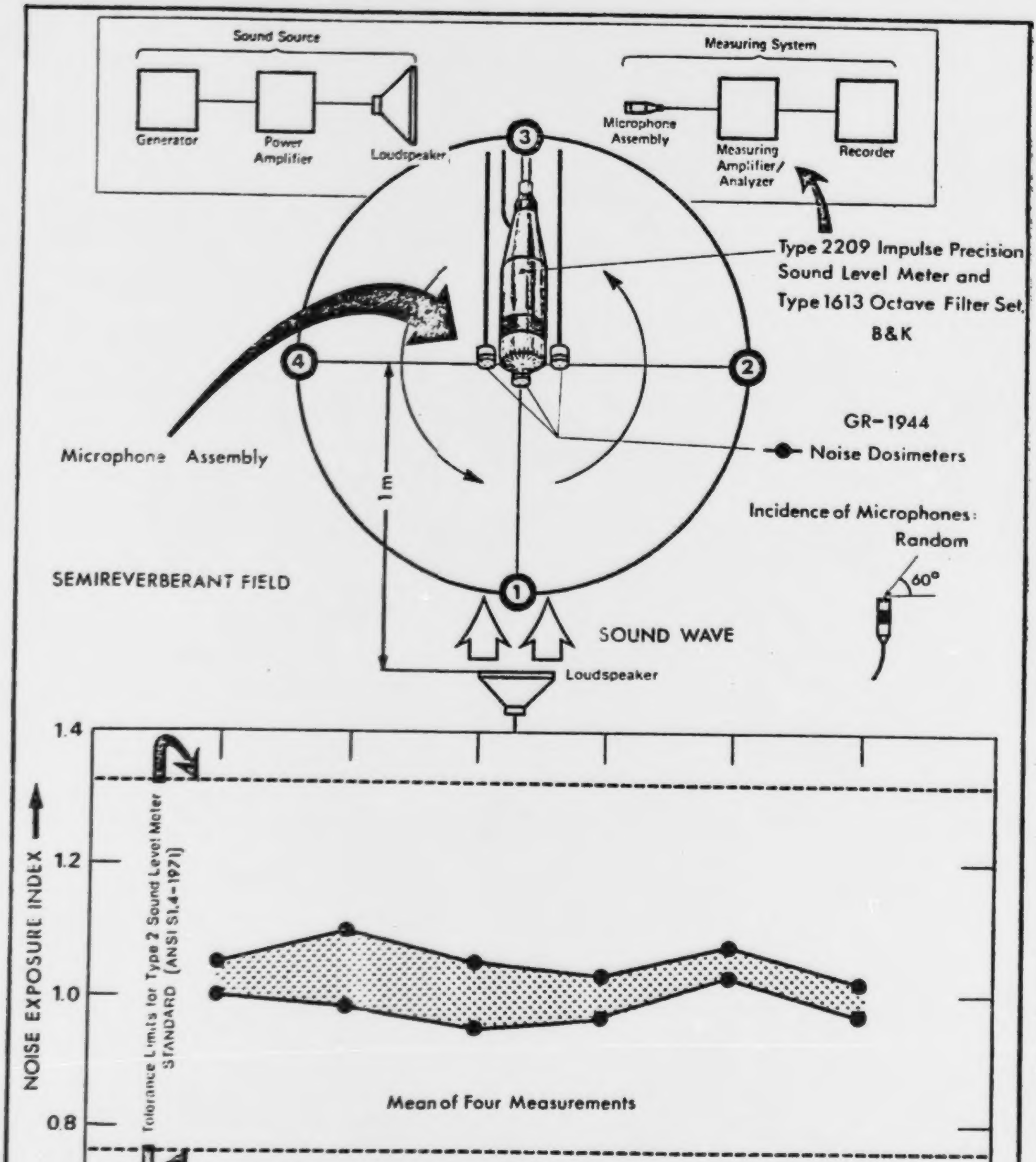


Fig. 7: Exposure results for three GenRad 1944 brand dosimeters.

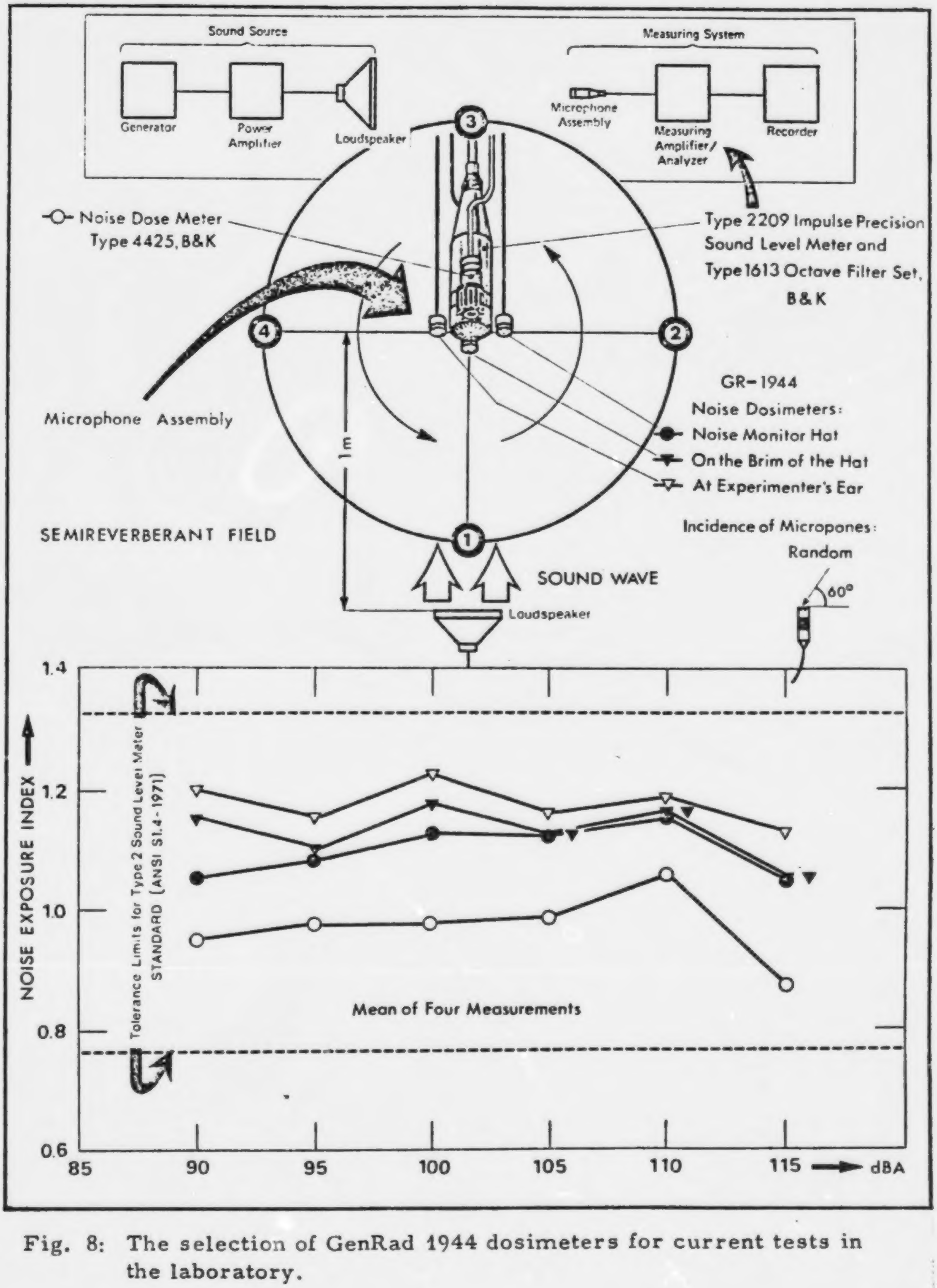


Fig. 8: The selection of GenRad 1944 dosimeters for current tests in the laboratory.

to be attached on the brim of the hat and at the experimenter's ear. A fourth, Type 4145, 1 in. B and K condenser microphone, was used as input to a B and K Type 2209 sound level meter. The output of the sound level meter was fed into a B and K Type 2306 level recorder.

3. 1. 3. The Laboratory Test of the Noise Monitor Hat

A possible design of such a noise monitor hat is illustrated (Fig. 9). The basic idea of this design is to place the microphone as near to the ear as possible and in such a way that it does not disturb the worker. There were two external GenRad 1944 dosimeters used. A fourth, Type 4145, 1 in. condenser microphone, was placed on a stand at a vertical angle of 60° (angle of incidence), next to the left ear.

The physical setup of the tests had the subject wearing the hat and ear muffs, and sitting 1 meter away from a loud speaker. The loud speaker was receiving the amplified output of a B and K, Type 1402, random noise generator. The measurements were carried out with the subject facing 0°, 90°, 180° and 270° relative to the loud speaker, and for the sound levels 90, 95, 100, 105, 110 and 270 dBA. The results were averaged. For each measurement, after the sound level was set, an octave band analysis was done on the noise. The centre frequencies of these bands are 31.5, 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz. The reading is taken from the output of the graphic recorder in order to get the average level.

Approximate agreement with measured total noise and total noise estimated from the octave-band noise levels indicates reasonably constant conditions during the test period (± 1 dBA).

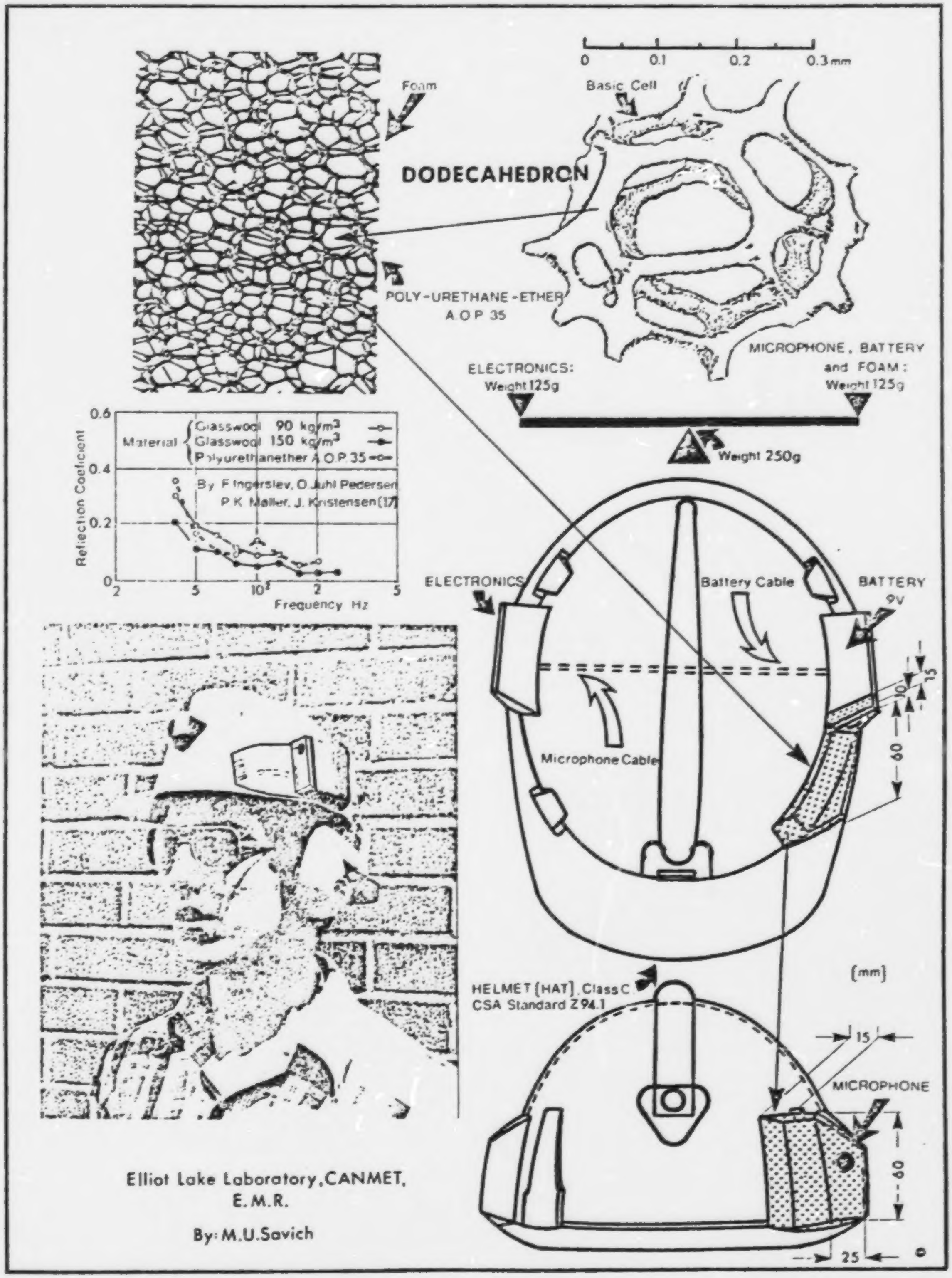

0
0.1
0.2
0.3 mm
Foam
Basic Cell
DODECAHEDRON
POLY-URETHANE-ETHER
A.O.P. 35
ELECTRONICS:
Weight 125g
MICROPHONE, BATTERY
and FOAM:
Weight 125g
Weight 250g
Reflection Coeficient
0.6
0.4
0.2
0
Material
Glasswool 90 kg/m3
Glasswool 150 kg/m3
Polyurethanether A.O.P. 35
By F. Ingerslev, O. Juhl Pedersen
P.K. Møller, J. Kristensen (17)
2
5
10²
2
5
Frequency Hz
ELECTRONICS
Battery Cable
BATTERY
9V
15
10
60
Microphone Cable
[mm]
HELMET (HAT), Class C
CSA Standard Z94.1
15
MICROPHONE
60
25
Elliot Lake Laboratory, CANMET,
E.M.R.
By: M.U.Savich

Fig. 9: Noise monitor hat.

Three tests were performed:

1) Noise monitor hat, unlined;

2) Noise monitor hat lined with Eccodamp M. G. foam; and

3) Noise monitor hat lined with Poly-urethane-ether AOP-35.

3. 1. 3. 1. Noise Monitor Hat, Unlined

The noise monitor hat, and the GenRad 1944 noise dosimeter with microphone on the brim of the hat, had higher readings than the third, which was on the ear muff by the ear (Fig. 10). The readings from the noise monitor hat were higher than either of the other two. The high readings were caused by reflection of sound off the hard hat. All readings of the noise monitor hat were without tolerance limits, except the reading at 115 dBA.

3. 1. 3. 2. Noise Monitor Hat Lined With Eccodamp MG Foam

To eliminate reflection of sound off the hard hat, sound absorbing Eccodamp MG* was glued to the hat in the area of the microphone (Fig. 9 and 11). The manufacturer states that the acoustic absorption properties of this product are equivalent or superior to the AOP-35, usually used in Europe (16).

With Eccodamp MG foam, the readings from the noise monitor hat and the dosimeter with the microphone on the brim of the hat were close, but outside of tolerance limits. The third dosimeter had its microphone on the ear muff, and all readings were as in previous tests.

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* Product of Emerson and Cuming Inc., Canton, Mass.

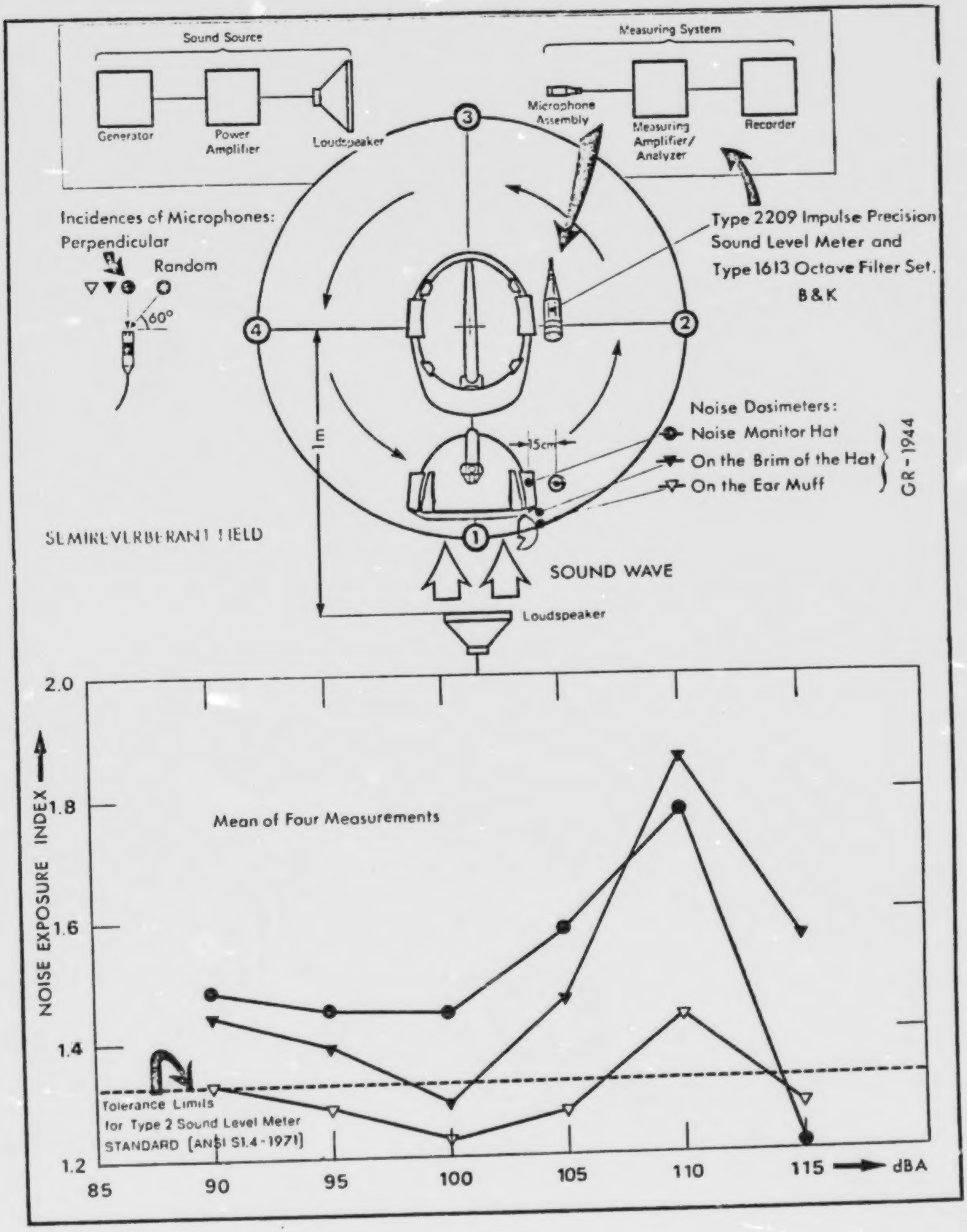


Fig. 10: Noise monitor hat, unlined.

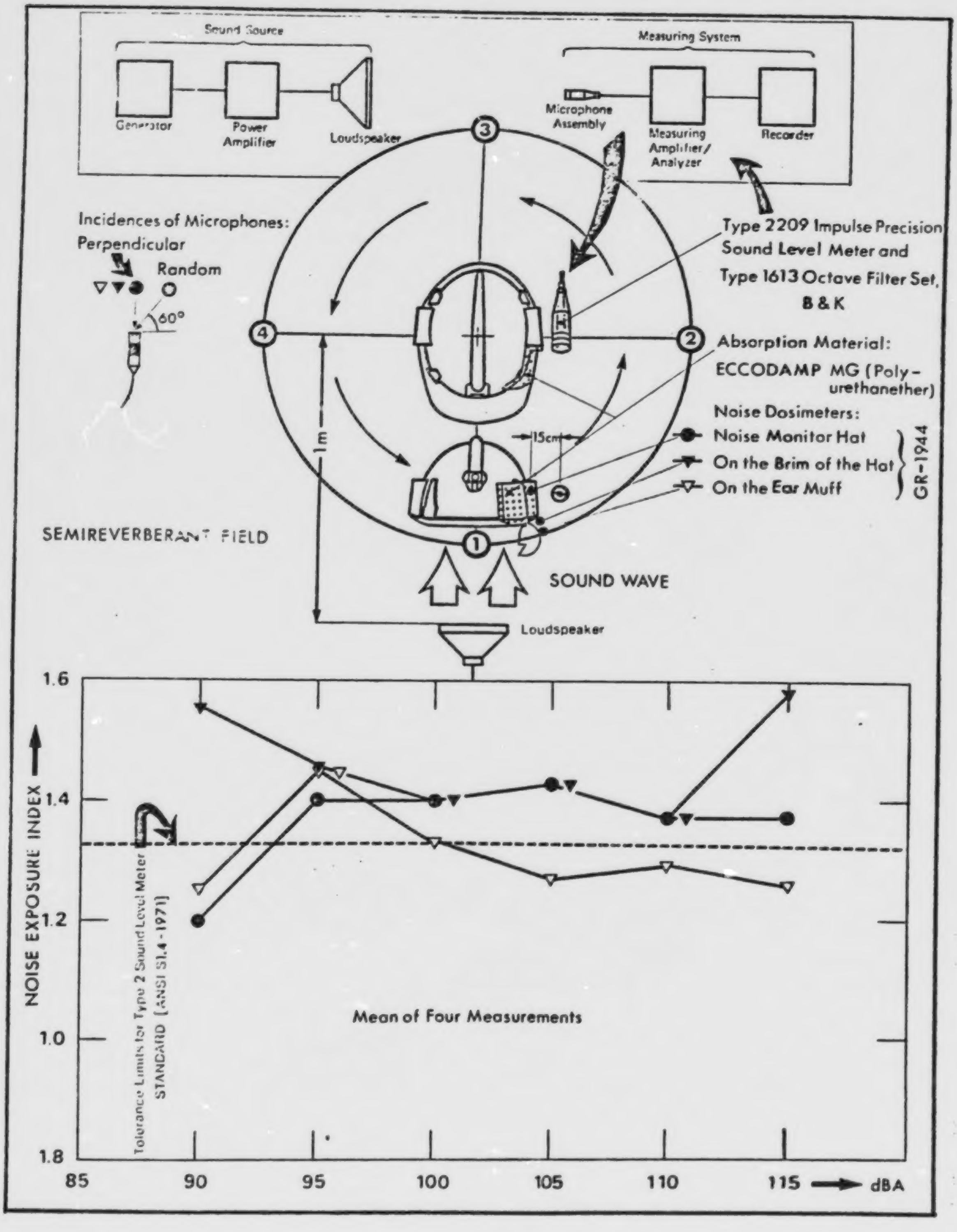


Fig. 11: Noise monitor hat lined with Eccodamp MG foam.

3.1.3.3. Noise Monitor Hat Lined With Poly-Urethane-Ether, AOP-35

In order to gain experimental evidence of the sound absorption of different materials, measurements were carried out on foamed poly-urethane-ether AOP-35, which resulted in a decrease in all readings. The influence of the helmet was still high, but readings from the noise monitor hat and those from the experimenter's ear were much the same, and within tolerance limits (Fig. 12). The dosimeter with the microphone on the brim of the hat, at 95 dBA and 100 dBA had a higher reading, but was close to the tolerance limit line.

3.2. Tests of the Noise Monitor Hat in the Mine

The remaining tests were done in the mine at the following work places:

- jackleg operator;
- two-boom jumbo operator;
- three-boom jumbo operator;
- scooptram operator;
- scraper operator;
- crusher operator; and
- compressor operator.

Results of the tests were extremely good and the accuracy was high (± 1.5 dB) (Table 2). In two cases readings were the same, and in another two, they were close. In this practical situation where the angle of incidence of sound varies widely the differences on the average were small.

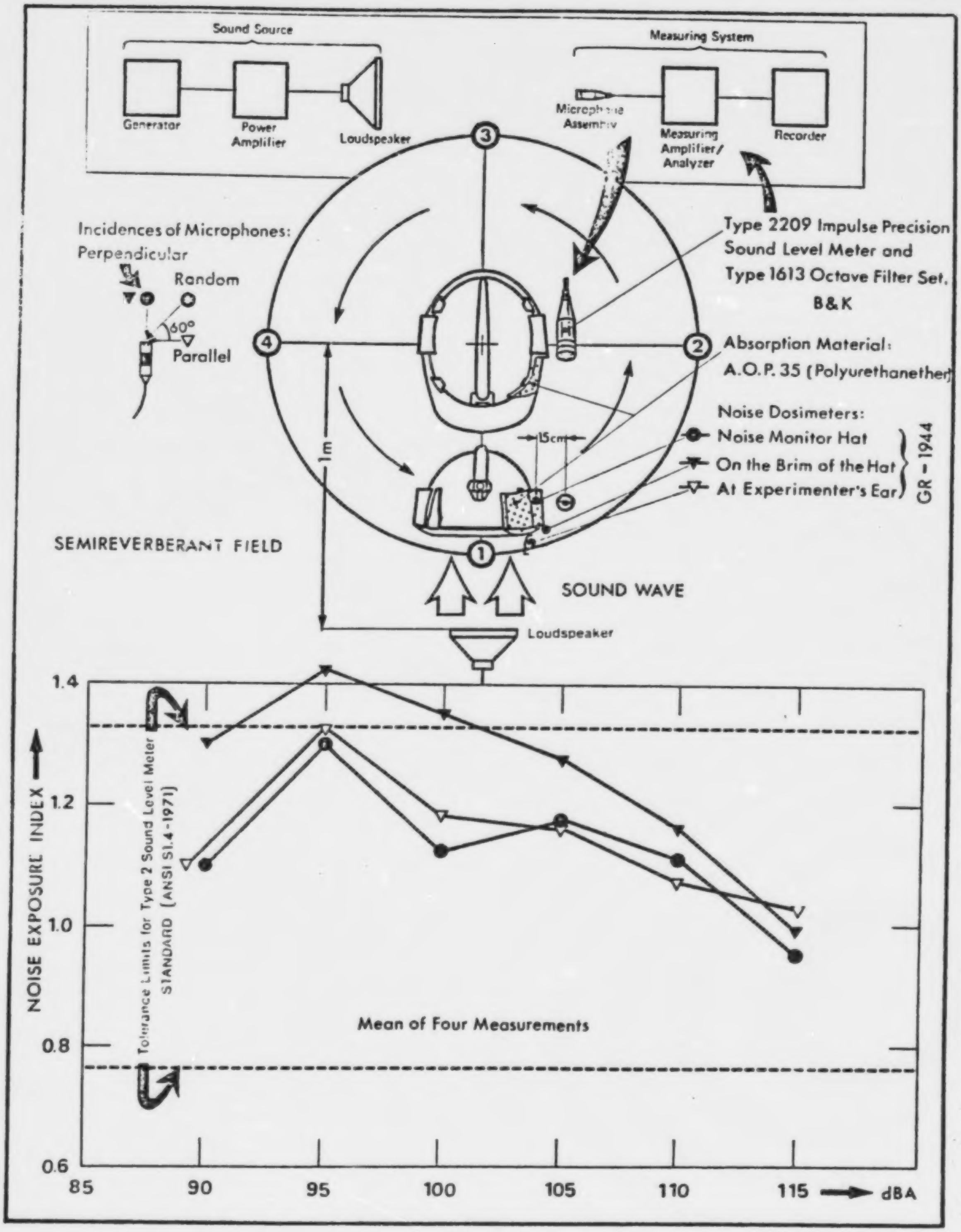
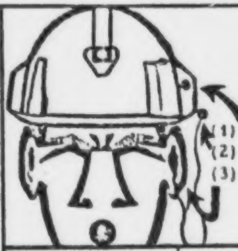


Fig. 12: Noise monitor hat lined with poly-urethane-ether AOP-35 foam.

TABLE 2

Evaluation of Noise Exposure Index in the Main Mining Operation Stations



(1) Noise Monitor Hat, Noise Dosimeter GR-1944
(2) On the Brim of the Hat, } Noise Dose Meter
(3) At Operator's Ear, } Type 4425 B & K

No.	Job Category	1		2		3		Sampling Time (h)	L_{eq} (dBA)++			
		NEI+	Exceeded 115 dBA	NEI	Exceeded 115 dBA	NEI	Exceeded 115 dBA		1	2	3	Difference (1)-(2) or (3)
1	Jackleg Operator	0.67	Yes	0.76	Yes	-	-	5:00	90.2	91.5	-	- 1.3
2	Jumbo (Two Boom)Operator	5.12	Yes	5.17	Yes	-	-	3:45	108	108	-	0
3	Jumbos (Three Boom)Operator	3.44	Yes	2.79	Yes	-	-	7:15	99.6	98.2	-	+ 1.4
4	Scooptram Operator	3.19	Yes	-	-	3.05	No	8:25	98	-	97.8	+ 0.2
5	Scraper Operator	1.24	Yes	-	-	1.38	Yes	8:15	91	-	91.7	- 0.7
6	Crusher Operator	3.57	Yes	3.59	Yes	-	-	7:45	99.4	99.4	-	0
7	Compressor Operator	1.12	Yes	-	-	1.35	Yes	8:00	90.6	-	91.6	- 1

NOTE: + Noise Exposure Index
++ Equivalent Continuous Sound Level

4. DISCUSSION

To bring our research on noise monitor hats together, there are three major aspects to which we wish to draw attention:

1. Time differences between the impulse of noise on the right and left ear are a consequence of the varying path lengths of sound waves. According to the "law of the first wave front", an ear closer to the noise will be more affected than one that is not (Fig. 13).

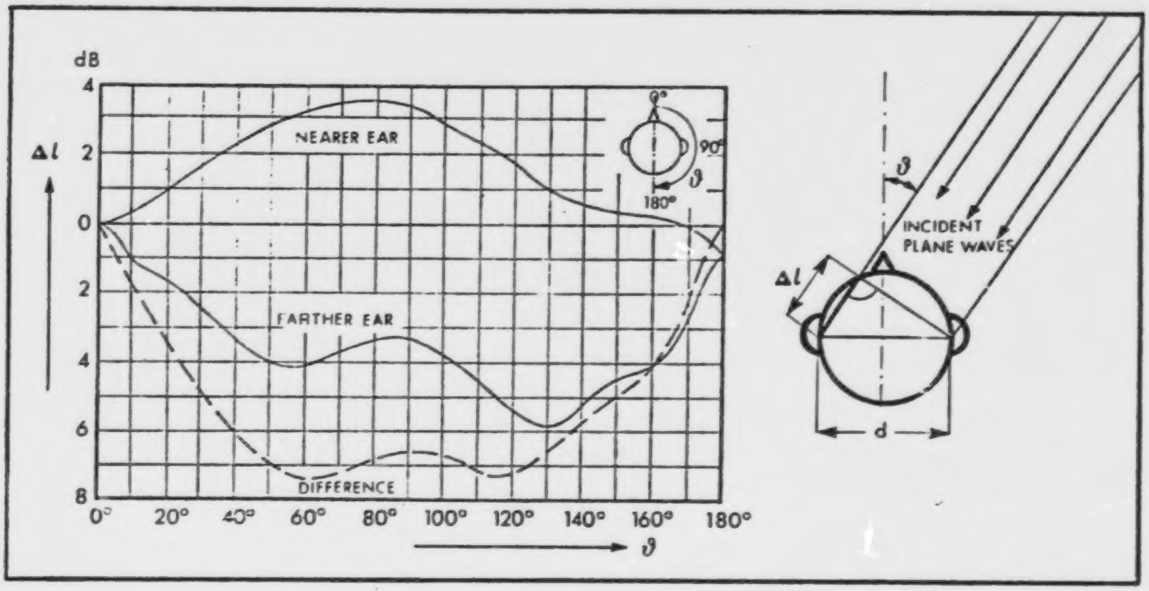


Fig. 13:. Differences in noise levels which act on the left and right ears ($\Delta \ell$), for discussion on the dependence of the source position in the horizontal plane (18).

In the equation for time differences, this represents a delay of:

$$\Delta t = \Delta \ell / c \qquad \text{Eq. 2}$$

taking into account the head's roundness, $\Delta \ell$ with a maximum of 24 cm, which means:

$$\Delta t_{max} \leq \frac{\Delta \ell_{max}}{c} \simeq 7 \times 10^{-4} s \qquad \text{Eq. 3}$$

where: c = 343 m/s at 20°C.

These time differences can be expressed as phase differences because:

$$\Delta\varphi = \omega\Delta t = 2\pi f\Delta t \qquad \text{Eq. 4}$$

If we take $\Delta\varphi = \pi$, we would see that from $f \simeq 700$ Hz, phase lag would become phase lead, because $\Delta\varphi > \pi$. Under normal conditions, when the start of a signal is heard, it is important which of the two ears first receives the impulse. This means that the time difference, and not the phase difference, is imperative, or - looking at it physiologically, the ear levels itself according to the first influence. From this we can conclude that left handed workers should have their microphones on the helmet's right side (Fig. 14). This is very important for Canadian purposes, because 12% of the work force is left-handed on the basis of random sampling in Rio Algom (19).

Further research topics should include noise and occupational hearing loss in relation to left and right-handed workers, and the developing science of ergonomics.

2. The space provided for exploration and maintenance is a requirement to ensure an acceptable level of operating efficiency. Vertical clearance for a tall man (plus shoes and helmet) is 193-198 cm (U.S. statistics), but larger openings are dependent on geological conditions and outer equipment (Fig. 15). The noise monitor hat is very rugged. The housings are resistant to impact, abrasion and chemical attack. The unit will withstand extremes of humidity and temperature.
3. The Federal Register states (13): "Noise exposure measurements shall be made with the personal noise dosimeter located at the top of the

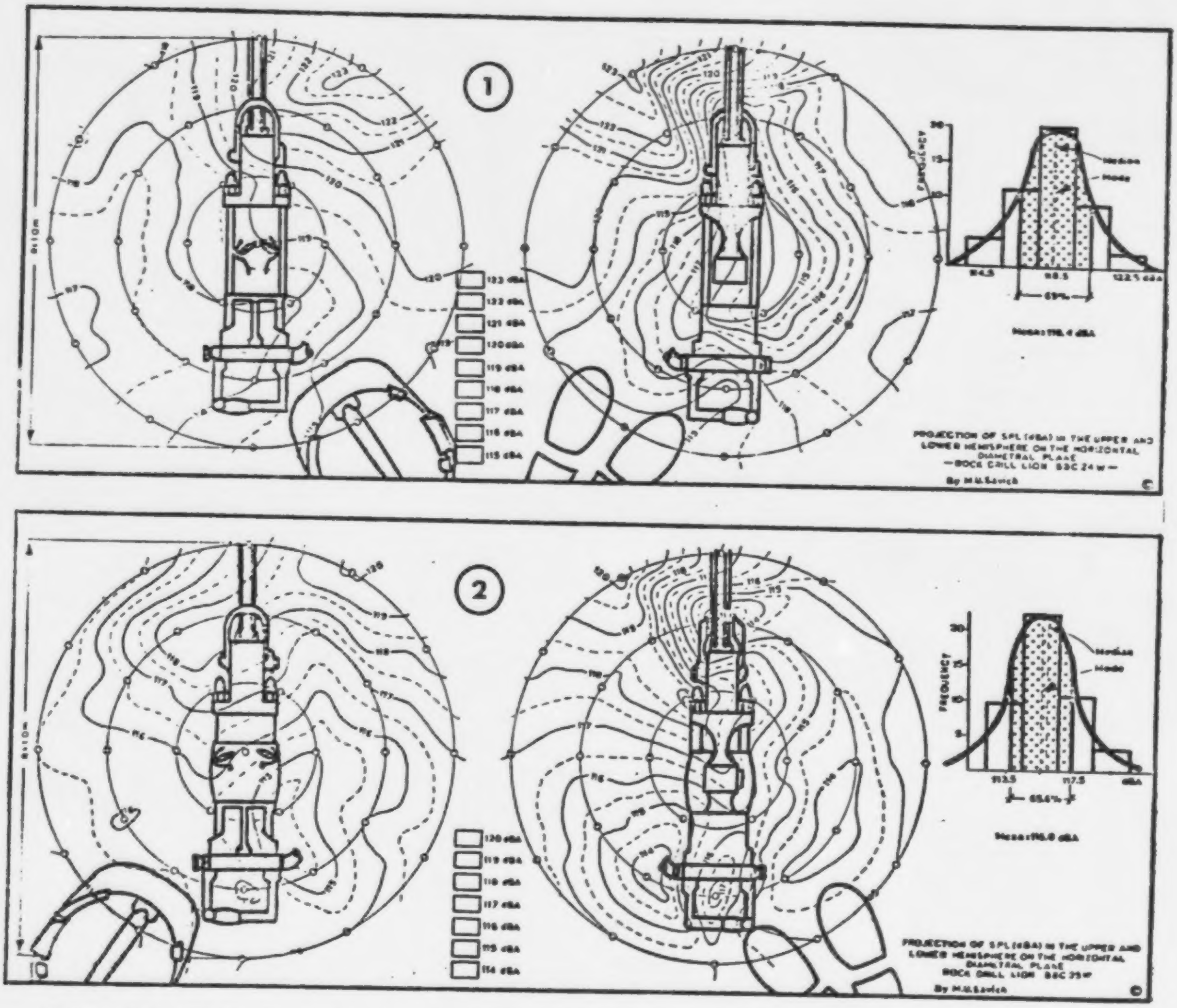

1
123 dBA
122 dBA
121 dBA
120 dBA
119 dBA
118 dBA
117 dBA
116 dBA
115 dBA
FREQUENCY
Median
Mode
114.5
118.5
122.5 dBA
69%
Mean: 118.4 dBA
PROJECTION OF SPL (dBA) IN THE UPPER AND LOWER HEMISPHERE ON THE HORIZONTAL DIAMETRAL PLANE
— ROCK DRILL LION BBC 24 W —
By M.U.Savich
2
120 dBA
119 dBA
118 dBA
117 dBA
116 dBA
115 dBA
114 dBA
FREQUENCY
Median
Mode
113.5
117.5
dBA
65.6%
Mean: 116.0 dBA
PROJECTION OF SPL (dBA) IN THE UPPER AND LOWER HEMISPHERE ON THE HORIZONTAL DIAMETRAL PLANE
ROCK DRILL LION BBC 25 W
By M.U.Savich

Fig. 14: Relation of noise monitor hat to the noise sources: (1) left-handed miner; and (2) right-handed miner.

shoulder, midway between the neck and the end of the shoulder with the microphone pointing in a vertical upward direction" (Fig. 16). It is clear that it is not possible to accept this regulation in the mines, because of the following:

- An attachment doesn't exist so that the microphone can stand vertically;

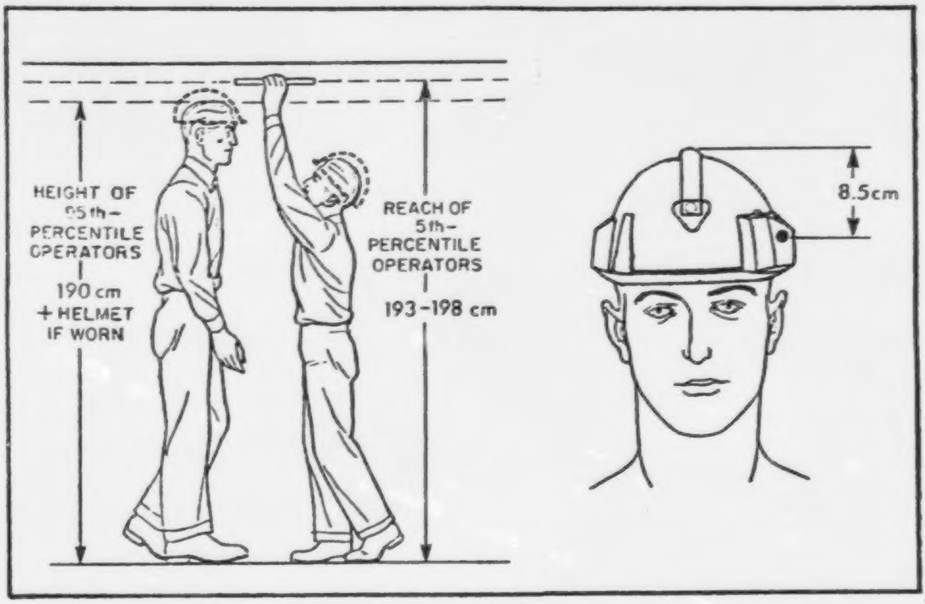

HEIGHT OF 95th-PERCENTILE OPERATORS
190 cm + HELMET IF WORN
REACH OF 5th-PERCENTILE OPERATORS
193-198 cm
8.5cm

Fig. 15: The vertical clearance for overhead controls is limited to 3-6 cm in practice. The noise monitor is in a very safe place on the hat.

- Water from above falls directly on the microphone membrane;
- Shoulders are used during work in the mines; and
- Shoulder application makes it impossible for the worker to pass through narrow openings.

It is clear from the foregoing analysis that the noise monitor hat has advantages over other systems.

5. CONCLUSIONS

The construction of the noise monitor hat has presented the main stand of the Elliot Lake Laboratory's research effort, moving toward automated, reliable and safe environment systems in mines which will enable high accuracy results to be obtained. Because of this we developed the design and testing technologies to meet the marketing needs that are

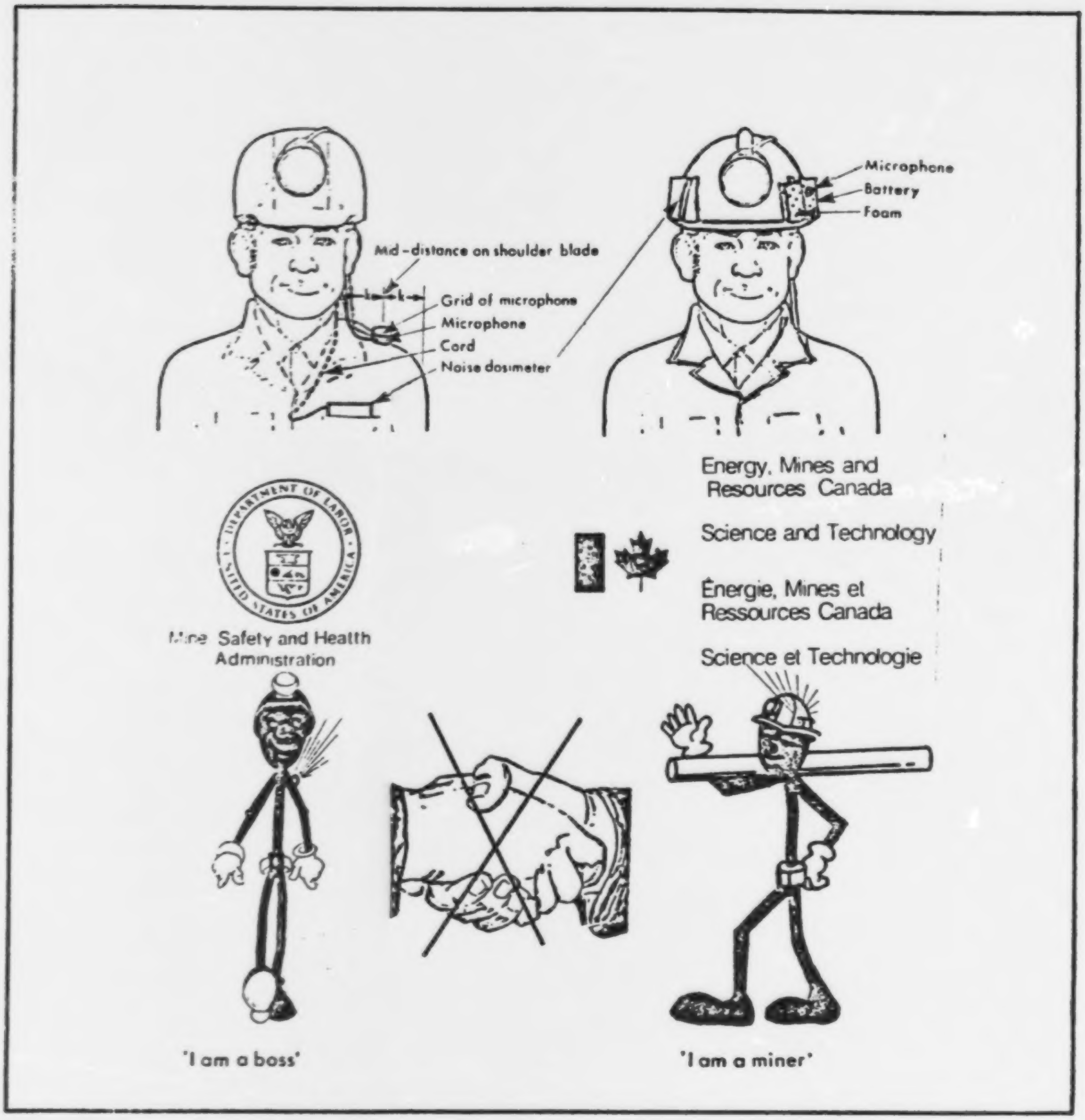

Mid-distance on shoulder blade
Grid of microphone
Microphone
Cord
Noise dosimeter
Microphone
Battery
Foam
Mine Safety and Health Administration
Energy, Mines and Resources Canada
Science and Technology
Énergie, Mines et Ressources Canada
Science et Technologie
'I am a boss'
'I am a miner'

Fig. 16: Disagreement between U.S. and Canada because of practical and safety reasons.

---

developing.

The laboratory test was conducted in a diffuse field and is not in accordance with the standard that is specified for Personal Noise Dosimeters, ANSI S1.25-1978. The accuracy of the field test has confirmed the correctness of our laboratory test (± 1.5 dB, better than the requirements of ANSI S1.25-1978). The final result of personal noise monitoring is a function of the statistical sampling of the work environment (20).

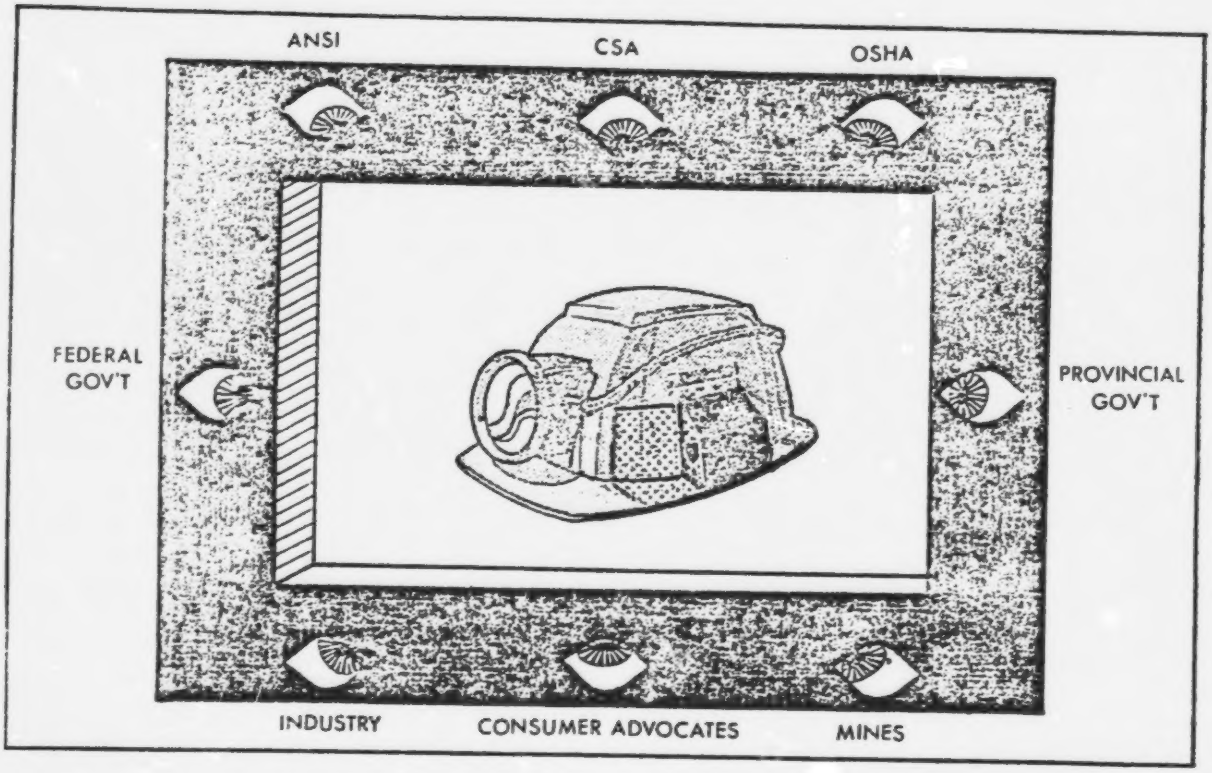
It is expected that, after this, more attention will be given to the Noise Exposure measurements in Canadian Mines.

The developed systems for Noise Exposure analysis are expected to have application to other Federal and non-Federal activities.

6. ACKNOWLEDGEMENTS

The author wishes to express his appreciation to F. Jackson, Mine Manager at Quirke Mine (Rio Algom), for approval of this publication. Grateful acknowledgement is given to P. Park, Safety Superintendent at Quirke Mine for his assistance in field work.

The author is grateful to R. Tervo, Manager, Elliot Lake Laboratory, CANMET, and W.B. Muir, Ground Control Engineer, Elliot Lake Laboratory, CANMET, for technical reviews of the paper. He acknowledges the contribution of G. Frappier and R. Seymour for assistance in the laboratory work.


ANSI
CSA
OSHA
FEDERAL GOV'T
PROVINCIAL GOV'T
INDUSTRY
CONSUMER ADVOCATES
MINES

You Are Not ALONE!

Vignette.

7. REFERENCES

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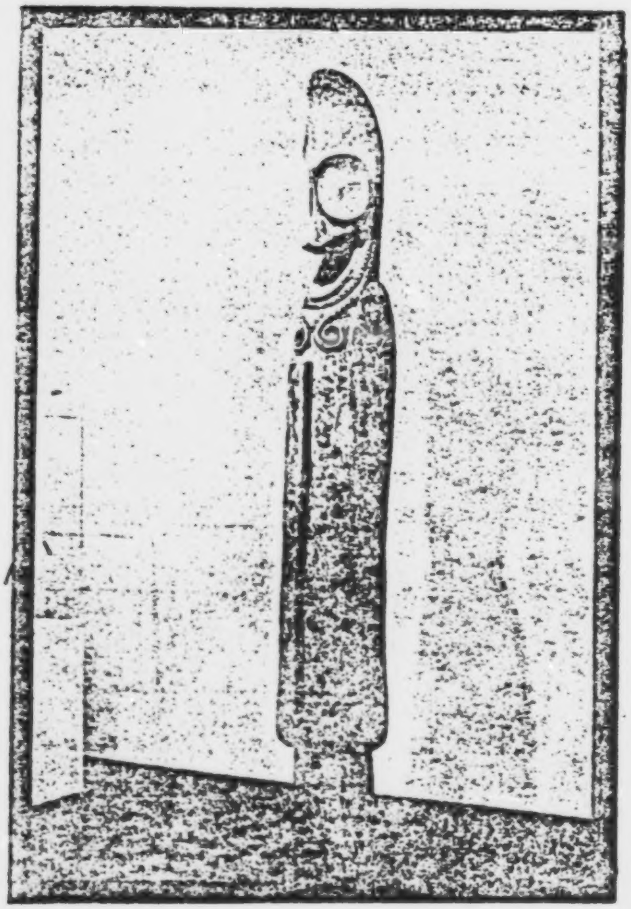

Vignette

Indian's resonant chamber (National Museum, Milwaukee, U.S.A.)

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VoL. 1 Report 12

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Developement of a noise monitor hat

1979

Presented at 18th International Conference

Science Research Work Safety, Yugoslavia

Oct. 1979

MESURE DU BRUIT DANS LES MINES

par

M. Savich*

RÉSUMÉ

Au cours des dix dernières années, de grands progrès ont été réalisés dans le domaine de la lutte contre le bruit dans les mines canadiennes. On a effectué des mesures dans le but de protéger l'ouïe du mineur et la méthode pourra un jour être complètement automatisée et informatisée. Plusieurs systèmes ont été mis au point pour la surveillance et le calcul du bruit dans les mines. Avec le présent système, la Commission des accidents du travail sera en mesure de juger correctement chaque plainte. Le système sera aussi très utile pour la Direction qui pourra prendre les mesures nécessaires en ce qui concerne l'entretien, le rendement au travail et la protection des travailleurs. De plus, la plus grande collaboration entre les travailleurs et la Direction aura des répercussions économiques et sociales bénéfiques.

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NOISE MEASUREMENT IN MINES

by

M. Savich*

ABSTRACT

In the last ten years Canadian mines have made great advances in the field of noise abatement. Measurements have been taken to protect the miners' hearing and this procedure will eventually be completely automated and connected into a computer system. Several systems were developed for monitoring and evaluating noise in the mines. With this system, the Workmen's Compensation Board will have the capability to correctly judge each claim. Management will have great use for this system, since they will be able to follow up on maintenance, work efficiency and protection. Also, the closer union between workers and management will have beneficial economic and social repercussions.

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* Research Scientist, Elliot Lake Laboratory, Mining Research Laboratories, Canada Centre for Mineral and Energy Technology, Department of Energy, Mines and Resources, Elliot Lake, Ontario.

1. INTRODUCTION

After a few years of experience with the application of standards contained in noise regulations and codes, more and more mining engineers in Canada have become involved in the problems associated with them, the way they are implemented and the high cost of compliance (1).

Standards for occupational noise exposure are not uniform in Canada. British Columbia uses criterion ISO*R 1999 Assessment of Occupational Noise Exposure for Hearing Conservation Purposes. The United States (and other parts of Canada) use a slightly different criterion from Occupational Safety and Health Acts (OSHA). Both criteria prescribe a maximum continuous exposure level of 90 dBA in the work environment. Below 90 dBA, ISO controls exposures down to 80 dBA. OSHA sets no limits below 90 dBA, but a proposal is pending to extend control by lowering it to 85 dBA.

These two criteria also differ in how they block out work periods. ISO permits averaging exposure over a 40 hour work week, but OSHA permits averaging over just an 8-hour work day.

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered.

The OSHA Standard has established the following priorities for compliance:

1. Feasible engineering controls, such as reducing the noise at the source, along the path, or in the employee's hearing zone.
2. Feasible administrative measures by limiting the exposure of the employee to noise through job rotation and production scheduling.

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* International Organization for Standardization.

3. Hearing protectors used as a temporary means of limiting noise exposure until engineering controls and administrative measures are implemented.

Where the engineering and administrative controls which have been implemented do not reduce the sound levels to within the permissible limits, the employer shall continue to develop and implement engineering and administrative controls as they become feasible (OSHA).

2. IMPLEMENTATION: INSTRUMENTS AND TECHNIQUES

The objective of industrial noise control and hearing conservation programs is to protect employees from permanent hearing loss in the speech frequency range. Noise measurement in Canadian Mines is directed towards the following objectives:

1. To satisfy regulation, code and standard requirements.
2. To place maximum emphasis on health and safety in the work place.
3. To disturb workers as little as possible during measurements.
4. To obtain information useful to management.
5. To keep in mind the low cost necessary for compliance.
6. To encourage manufacturers to build quieter equipment.

The Elliot Lake Laboratory, Mining Research Laboratories, Canada Centre for Mineral and Energy Technology (CANMET), Department of Energy, Mines and Resources, has organized its work to solve these requirements, so that mines, without great effort and high cost of compliance, can meet the goals set. up.

Over ten years ago, intensive work in Canadian mines began on personal protection. Audiometric tests and muffled rock drills were introduced (2). Today, a large amount of equipment on the market has some protective device against noise and vibration. Personal protective devices are constantly improving and noise measurements have become frequent. CANMET's techniques and experience were transferred to Canadian mines through publications, or assistance in measurements.

2.1. INSTRUMENTS FOR NOISE MEASUREMENT

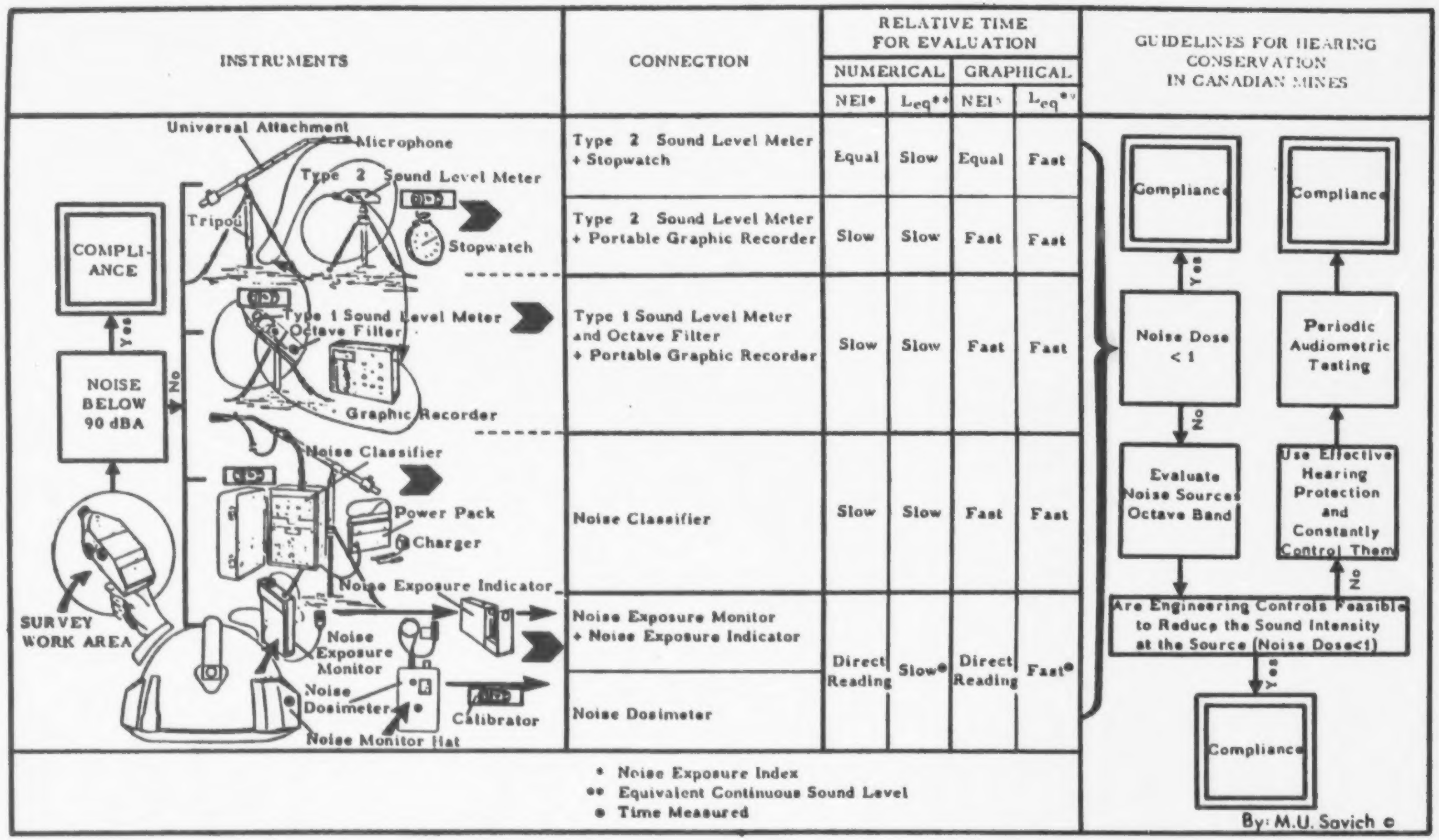
The basic instruments for noise measurement and for measuring noise exposure are (Fig. 1):

1. sound-level meter, a stopwatch and a data sheet for full-shift information;
2. graphical level recorder to provide a continuous record of the r.m.s. sound pressure level versus time, for full-shift information;
3. statistical analyzer to provide data for a manual analysis based on partial-shift information (used rarely in mines);
4. noise dosimeter to automatically integrate the sound energy received with regard to level and time;
5. profiling dosimeter to automatically integrate the amplitude distribution histograms, L_{eq} and time (new instruments).

The main effort is now being made in dosimetry. It is believed that therein lies the future of noise measurements in mines. Measurements using sound level meters and octave band analyzers are necessary when doing engineering controls. Because of this, a detailed account of noise dosimeter applications in Canadian mines will be made.

2.1.1. Graphical Method

A simple graphical method has been developed for calculating the Noise Exposure Index and the Equivalent Sound Level, based on measurements made during sampling periods (3).


INSTRUMENTS
SURVEY WORK AREA
NOISE BELOW 90 dBA
Yes
COMPLI-ANCE
No
Universal Attachment
Microphone
Tripod
Type 2 Sound Level Meter
Stopwatch
Type 1 Sound Level Meter
Octave Filter
Graphic Recorder
Noise Classifier
Power Pack
Charger
Noise Exposure Indicator
Noise Exposure Monitor
Noise Dosimeter
Calibrator
Noise Monitor Hat
GUIDELINES FOR HEARING CONSERVATION IN CANADIAN MINES
Noise Dose < 1
Yes
Compliance
No
Evaluate Noise Sources Octave Band
Are Engineering Controls Feasible to Reduce the Sound Intensity at the Source (Noise Dose<1)
Yes
Compliance
No
Use Effective Hearing Protection and Constantly Control Them
Periodic Audiometric Testing
Compliance
By: M.U. Savich ©

CONNECTION	RELATIVE TIME FOR EVALUATION			
	NUMERICAL		GRAPHICAL	
	NEI*	L_{eq}**	NEI*	L_{eq}**
Type 2 Sound Level Meter + Stopwatch	Equal	Slow	Equal	Fast
Type 2 Sound Level Meter + Portable Graphic Recorder	Slow	Slow	Fast	Fast
Type 1 Sound Level Meter and Octave Filter + Portable Graphic Recorder	Slow	Slow	Fast	Fast
Noise Classifier	Slow	Slow	Fast	Fast
Noise Exposure Monitor + Noise Exposure Indicator	Direct Reading	Slow●	Direct Reading	Fast●
Noise Dosimeter				

* Noise Exposure Index
** Equivalent Continuous Sound Level
● Time Measured

Fig. 1: Noise measurement steps and instrumentation used for noise dose measurement in mines.

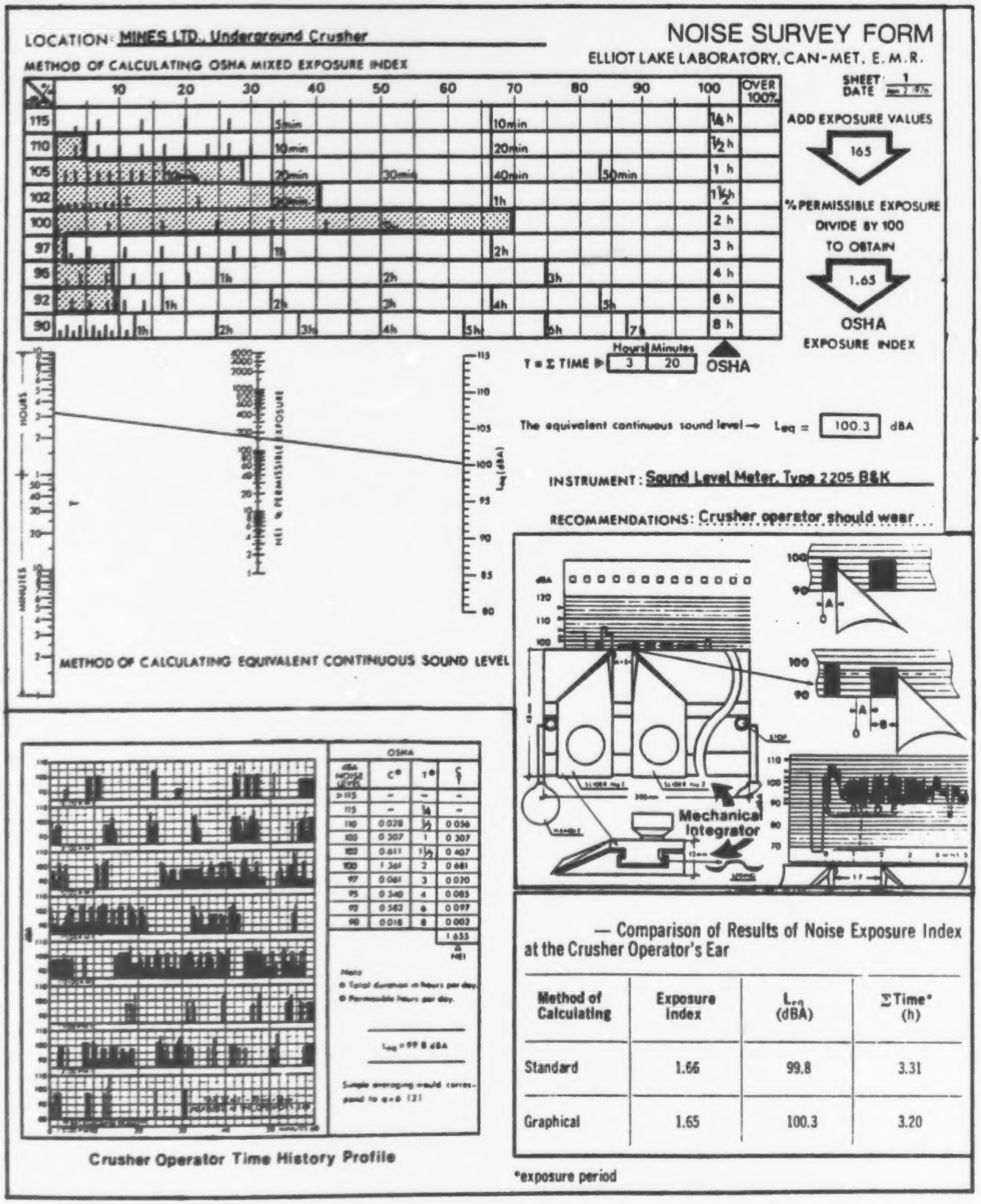
The evaluation of the total exposure time at various noise levels is done as follows (Fig. 2):

1. The average levels on paper tape are estimated and marked with a pencil to obtain an operator time history profile.
2. The base line is determined by the standard or act (here 90 dBA).
3. The lines of permissible noise levels according to the standard or act are drawn parallel to the base line with a coloured pencil.
4. With the mechanical integrator, the total time for which the noise level is at each selected value, 90, 92,..., 115 dBA, is integrated step by step. If the average recorded level is between levels, it is assigned to the higher level. Total time is expressed in minutes.
5. The values are transferred to the sheet, and the evaluation is made according to the OSHA exposure limits.

The exposures are added with the mechanical integrator and the total OSHA mixed exposure index, NEI, is read off on the upper scale.

The total time (T) evaluation can be done directly from the form used for calculating NEI with the mechanical integrator. An integrator is placed on the lowest horizontal edge of the table. The time is read from the table and the timed values of each level are added using slider No. 2. Slider No. 1 is used as a pointer to aid in the addition.

The accuracy of results is as good as that obtained by more complex numerical methods (Fig. 2). The method can be used to evaluate L_{eq} when specialized measuring instruments are not available. The time required to evaluate typical noise data is reduced by a factor of 10 or more, as compared to a purely numerical method.



NOISE SURVEY FORM
ELLIOT LAKE LABORATORY, CAN-MET, E.M.R.
METHOD OF CALCULATING OSHA MIXED EXPOSURE INDEX
ADD EXPOSURE VALUES
165
% PERMISSIBLE EXPOSURE DIVIDE BY 100 TO OBTAIN
1.65
OSHA EXPOSURE INDEX
METHOD OF CALCULATING EQUIVALENT CONTINUOUS SOUND LEVEL
HOURS
MINUTES
NEI % PERMISSIBLE EXPOSURE
Leq (dBA)
Mechanical Integrator
SLIDER No. 1
SLIDER No. 2
Crusher Operator Time History Profile

LOCATION: MINES LTD., Underground Crusher

SHEET: 1

T = Σ TIME ▶ Hours 3 Minutes 20 OSHA

The equivalent continuous sound level → Leq = 100.3 dBA

INSTRUMENT: Sound Level Meter, Type 2205 B&K

RECOMMENDATIONS: Crusher operator should wear ....

OSHA			
dBA NOISE LEVEL	C●	T●	C/T
>115	–	–	–
115	–	1/4	–
110	0.028	1/2	0.056
105	0.307	1	0.307
102	0.611	1 1/2	0.407
100	1.361	2	0.681
97	0.061	3	0.020
95	0.340	4	0.085
92	0.582	6	0.097
90	0.016	8	0.002
			1.655

NEI

Note
● Total duration in hours per day.
● Permissible hours per day.

L_{eq} = 99.8 dBA

Simple averaging would correspond to q=6 (2)

— Comparison of Results of Noise Exposure Index at the Crusher Operator's Ear

Method of Calculating	Exposure Index	L_{eq} (dBA)	ΣTime* (h)
Standard	1.66	99.8	3.31
Graphical	1.65	100.3	3.20

*exposure period

Fig. 2: Using the mechanical integrator to determine the exposure time from a graphic level recorder output (Time History Profile). (1) Choose a level (here 100 dBA). Place "0" of rule (Slider No. 1) at first point; move Slider No. 2 to second point, as shown. (2) Move entire rule to the right, until the left edge of Slider No. 2 rests on the next point, etc.

2.1.2. Noise Monitor Hat

One of the problems in measuring the noise exposure in Canadian mines is that the measuring instruments should be permanently located at the operator's ear. The Elliot Lake Laboratory has solved this problem, that is, to measure the noise exposure with the Noise Monitor Hat by a simple method which will meet the criteria (4,5) Fig. 3).

The construction of the noise monitor hat has presented the main stand of the Elliot Lake Laboratory's research effort, moving toward automated, reliable and safe environment systems in mines which will enable high accuracy results to be obtained.

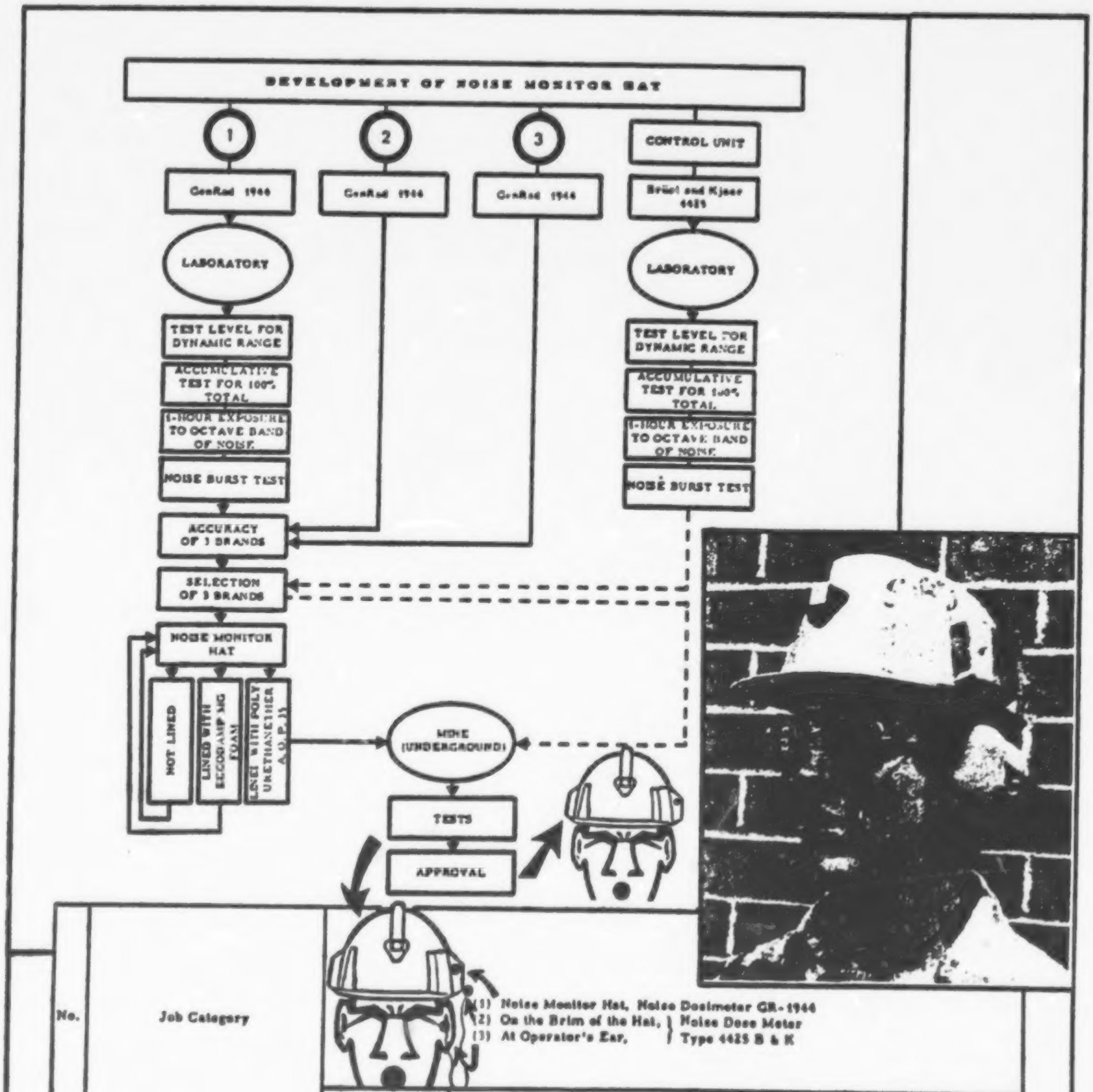
The accuracy of the field test has confirmed the correctness of our laboratory test (Fig. 3). The final result of personal noise monitoring is a function of statistical sampling of the work environment.

It is expected that, after this, more attention will be given to Noise Exposure measurements in Canadian mines.

2.1.3. Noise Monitor Gun

Noise Exposure Index (NEI) measurements were made during full shifts on the basis of the work cycle, or short-time measurement. The full-shift NEI measurements have yet to serve in a suitable and required application. The cause is three-fold:

1. The dosimeters are impractical to wear.
2. Damage to the microphones was frequent, and in some cases, workers lost the dosimeters altogether.
3. Instrument prices are forbidding, so much so, that management has balked at making measurements on a routine basis, as regulations require.


DEVELOPMENT OF NOISE MONITOR HAT
1
2
3
CONTROL UNIT
GenRad 1944
GenRad 1944
GenRad 1944
Brüel and Kjaer 4425
LABORATORY
LABORATORY
TEST LEVEL FOR DYNAMIC RANGE
TEST LEVEL FOR DYNAMIC RANGE
ACCUMULATIVE TEST FOR 100% TOTAL
ACCUMULATIVE TEST FOR 100% TOTAL
1-HOUR EXPOSURE TO OCTAVE BAND OF NOISE
1-HOUR EXPOSURE TO OCTAVE BAND OF NOISE
NOISE BURST TEST
NOISE BURST TEST
ACCURACY OF 3 BRANDS
SELECTION OF 3 BRANDS
NOISE MONITOR HAT
NOT LINED
LINED WITH ECCODAMP MG FOAM
LINED WITH POLY URETHANETHER A.O.P.35
MINE (UNDERGROUND)
TESTS
APPROVAL
(1) Noise Monitor Hat, Noise Dosimeter GR-1944
(2) On the Brim of the Hat,
(3) At Operator's Ear,
Noise Dose Meter Type 4425 B & K

No.	Job Category	1		2		3		Sampling Time (h)	L_{eq} (dBA)++			
		NEI+	Exceeded 115 dBA	NEI	Exceeded 115 dBA	NEI	Exceeded 115 dBA		1	2	3	Difference (1)-(2) or (3)
1	Jackleg Operator	0.67	Yes	0.76	Yes	-	-	5:00	90.2	91.5	-	- 1.3
2	Jumbo, Two Boom Operator	5.12	Yes	5.17	Yes	-	-	3:45	108	108	-	0
3	Jumbee, Three Boom Operator	3.44	Yes	2.79	Yes	-	-	7:15	99.6	98.2	-	+ 1.4
4	Scooptram Operator	3.19	Yes	-	-	3.05	No	8:25	98	-	97.8	+ 0.2
5	Scraper Operator	1.24	Yes	-	-	1.38	Yes	8:15	91	-	91.7	- 0.7
6	Crusher Operator	3.57	Yes	3.59	Yes	-	-	7:45	99.4	99.4	-	0
7	Compressor Operator	1.12	Yes	-	-	1.35	Yes	8:00	90.6	-	91.6	- 1

NOTE: + Noise Exposure Index
++ Equivalent Continuous Sound Level

Fig. 3: Flow sheet diagram of noise monitor hat development and field tests in main mining operation stations.

Because of this, cyclical measurements are better and simpler. In this case many work stations are surveyed in a day and there is the advantage of promptly supervised measurements with results immediately evaluated. The results are immediately reported to the worker, either verbally or in writing. This hopefully influences the worker to consider protecting himself, starting right away (Fig. 4).

Through this method, the worker is also befriended by management and he is given the capability to discuss the environmental problem with his colleagues and his union. The principle of full information for workers has already materialized; during measurements, noise records are included with the paychecks (Fig. 4). The bonus report (mine unit activity report) contains information regarding work cycles or units of production. Noise data per cycle of production are adapted to the mine unit activity report. In the time office, data from foremen and environmental engineers are sorted and handed to the computer centre. The computer prints out 5 samples of payment books with noise records that go to:

1. the pay office
2. the engineering office (final control)
3. the time office (final control)
4. environmental engineering
5. files storage.

The flow diagram was constructed and should be finalized through modification and adaptation by the management of each mine. Thus, the following is recommended:

1. Full shift noise dose measurements should be done only in places of no cyclical work, mainly work places where there is less noise.
2. Apply short cyclical measurements in other places and immediately

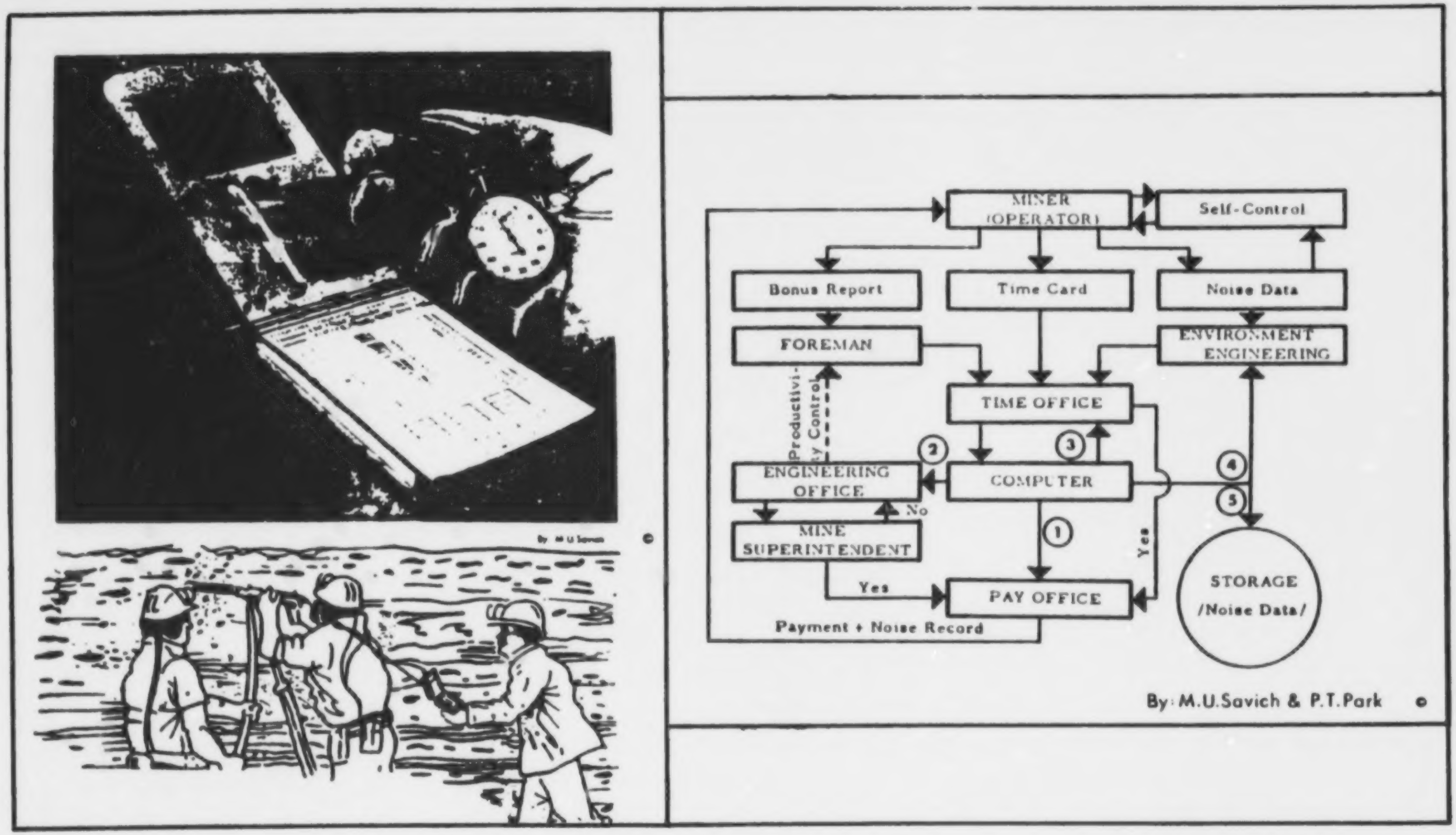

By M U Savich
MINER (OPERATOR)
Self-Control
Bonus Report
Time Card
Noise Data
FOREMAN
ENVIRONMENT ENGINEERING
TIME OFFICE
Productivity Control
②
③
ENGINEERING OFFICE
COMPUTER
④
⑤
No
MINE SUPERINTENDENT
①
Yes
Yes
PAY OFFICE
STORAGE /Noise Data/
Payment + Noise Record
By: M.U.Savich & P.T.Park ©

Fig. 4: The Noise Monitor Gun in use during a work cycle or short-time measurement. Cross-payment flow diagram; improving noise environmental control.

evaluate results using the graphical method.

A short comparative analysis was carried out between the two methods of measuring: full-shift and cycle (short) measurements (Table 1).

Table 1 - Comparison between full-shift and cycle measurements of the equivalent continuous sound levels

Operation	Measurement	No. Samples	Leq (dBA)	
			Act. Mean	Std. Dev.
Jumbo operator	Cycle (short)	5	99.26+	2.52
	Shift	9	100.5	2.42
Rockbolter	Cycle (short)	3	98.47+	0.76
	Shift	8	100.35	8.47
Driller	Cycle (short)	39	106.46+	5.98
	Shift	18	107.56	7.85

+ Correction: + 1 dB (influence of noise exposure during travelling from the shaft to working area and back).

Even though the number of measurements is small, the values are nearly equal.

2.1.4. Measurements of the Attenuation of Ear Muffs and the Noise Exposure Index

Constant control of ear muff use is necessary in mines because 50% of miners use them, while 40% prefer plugs. Only ~3% use both ear muffs and plugs, and 7% of miners use hearing protectors occasionally or not at all.

Measurements showed that ear muff 'D' had poor attenuation (Table 2). To find the reason for the poor attenuation, we used the same ear muff on the same worker, and on the same machine (Table 2, No. 9). Under ideal conditions, the ear muff provided ideal results (>26.9 dBA), while under working conditions, attenuation was only about half of that (12.6 dBA).

Measurements were done with a noise monitor vest using two dosimeters (6) (Fig. 5). Simultaneously, with the noise monitor vest, the Noise Exposure

Table 2 - Attenuation of ear muff 'D' in a local Elliot Lake mine

No.	Occupation	Ear Muff	Band	D (cm)	Equivalent Continuous Sound Level - L_{eqs} (dBA)						Average Attenuation (dBA)	Remarks
					Left Muff			Right Muff				
					Over	Under	Diff.	Over	Under	Diff.		
1	Jackleg (Driller)	D		14.7	114.6	98.2	16.4	114.9	105	9.9	13.15	Long hair
2	Jackleg (Driller)	D		14	111.8	93.2	18.6	112.7	94.6	18.1	18.35	Ideal condition
3	Jackleg (Helper)	D		13.8	112.6	108	4.6	114.3	98.8	15.5	10.05	Long hair
4	Rock Bolter (Helper)	D		13.6	114.6	106.2	8.4	115.2	104.9	10.3	9.35	
5	Slusherman	D		13.7	93.6	80.4	13.2	94.4	86.1	8.3	10.75	Lack spring pressure
6	Slusherman	D		14	96.8	<80	>16.8	97.5	<80	>17.5	>17.5	
7	JC800 Scooptram	D		14.2	102	89.5	12.5	101	91.4	9.6	11.05	New liner
8	ST8 Scooptram	D		13.3	101.7	91.6	10.1	101.5	89.8	11.7	10.9	
Σ	Mean			13.91	105.96	93.39	12.58	106.44	93.83	12.61	12.59	
	Std. Dev.			0.42	8.43	10.47	4.73	8.69	8.83	3.85	3.38	
* 9	2-Boom Jumbo	D		14	107.2	80	27.2	106.6	80	26.6	26.9	Ideal condition
9	2-Boom Jumbo	D		14				106.8	93.7	13.1	13.1	Working condition

* Same ear muff:
(1st case) - operator does not move his neck or head, ideal conditions.
(2nd case) - operator under normal working conditions.

Index can be measured using the same principle applied to noise monitor guns. Likewise, the noise monitor gun can be used to measure ear muff attenuation. From Table 2 we can see that noise at the same machine varies by ± 1 dB. One only needs to take off the microphone and cable and to mount it under the ear muff.

Measurements are indispensable, and workers must constantly be reminded to use ear muffs and plugs when the noise reaches levels of 105 dBA or more.

2.1.5. New noise dosimeter instruments

All noise dosimeter manufacturers made an effort to have their instruments meet existing regulations and to give final results in terms of Noise Exposure Index (NEI). In practice this was shown to be inadequate because the following factors were not considered:

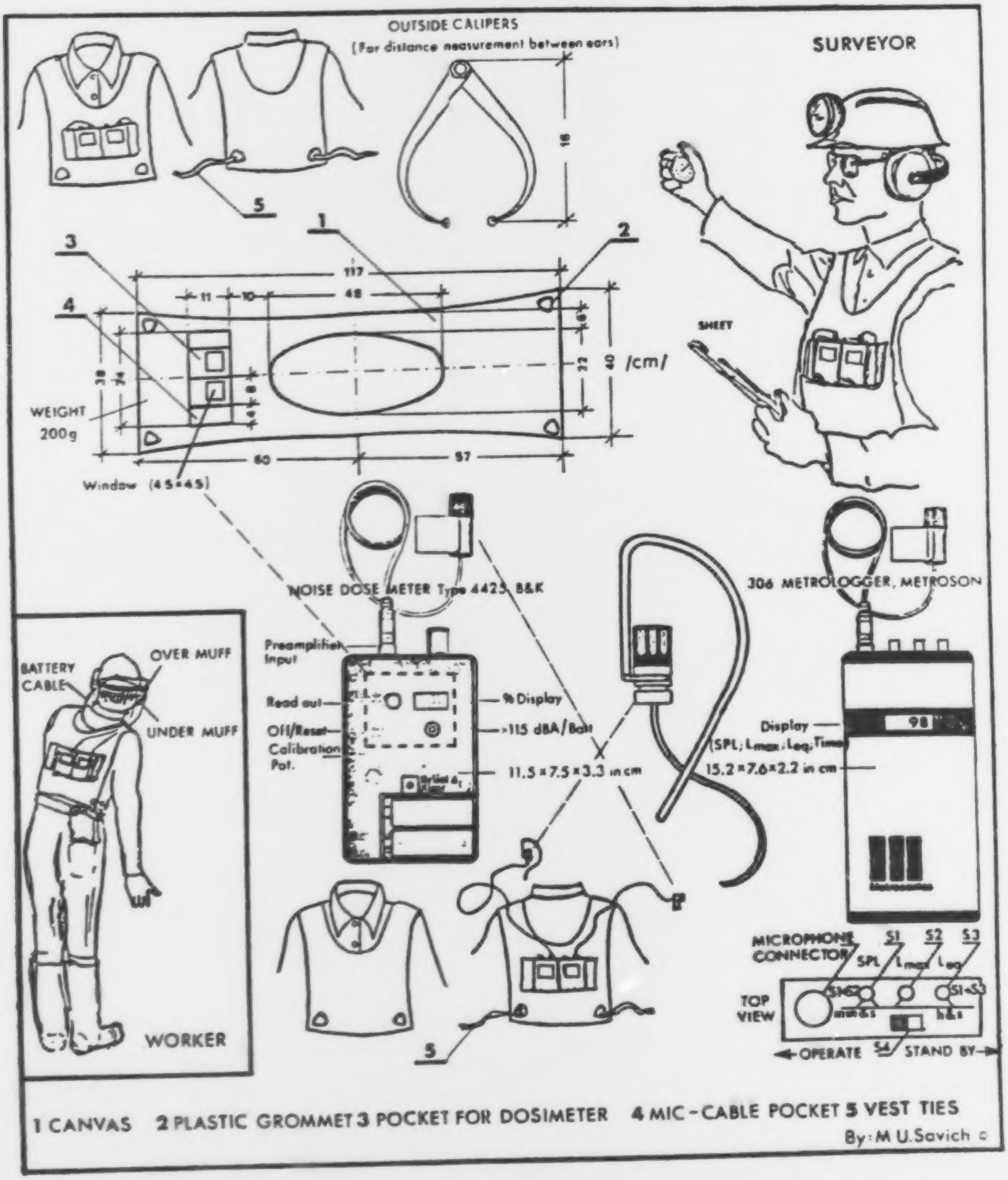

OUTSIDE CALIPERS
(For distance measurement between ears)
18
SURVEYOR
SHEET
5
1
2
3
4
117
11
10
48
10
38
24
8
4.5
22
40
/cm/
WEIGHT 200g
60
57
Window (4.5×4.5)
NOISE DOSE METER Type 4425 B&K
306 METROLOGGER, METROSON
Preamplifier Input
Read out
Off/Reset
Calibration Pot.
% Display
>115 dBA/Batt
11.5×7.5×3.3 in cm
Display
(SPL; Lmax; Leq; Time)
15.2×7.6×2.2 in cm
98
BATTERY CABLE
OVER MUFF
UNDER MUFF
WORKER
5
MICROPHONE CONNECTOR
S1
S2
S3
SPL
Lmax
Leq
TOP VIEW
S1+S2
S1+S3
min&s
h&s
OPERATE
S4
STAND BY
1 CANVAS 2 PLASTIC GROMMET 3 POCKET FOR DOSIMETER 4 MIC-CABLE POCKET 5 VEST TIES
By: M U.Savich ©

Fig. 5: The noise dosimeter vest in use during ear muff attenuation measurements.

1. Sound Pressure Level (SPL), so that we don't have to purchase a separate instrument for its measurement.
2. Maximum Level (L_{max}), to make it possible for us to properly apply personal hearing protection.
3. Equivalent continuous noise level (L_{OSHA}) or L_{eq}, the accepted risk of hearing loss (>90 dBA or >85 dBA) during short-time or normal 8-hour working day.
4. Time (T), during L_{OSHA} or L_{eq}.

Metrosonics Inc. started in the opposite direction. They constructed an instrument (actually a simplified dosimeter) that gives results which when combined make it easy to calculate the NEI through the numerical or graphical method (Fig. 2).

The 306 Metrologger digital sound level analyzer is a pocket-size computer designed for automatic sound level analysis over a selected 64 dB range (Fig. 6). The internal computer circuit samples the amplitude, calculates and provides 4 digit displays of SPL, L_{max}, L_{eq} or L_{OSHA}, and the time duration of the sampling period. The samples are converted to digital format and stored. The PROM (Program Modules) replacement feature provides the ability to change the functions of the 306 Metrologger (Table 3).

The 301 Metrologger is designed for processing and storing sound level information. The 651 Metroreader is a desk analyzer with an internal printer. The 651 reader interrogates the 301's memories (similar to 306 Metrologger), calculates noise descriptors and simultaneously prints out all information on a built-in thermal printer. A variety of PROM (Program Modules) in the program library make the Metrologger multi-functional (Table 4).

The Elliot Lake Laboratory made the suggestion to Metrosonic Inc. to connect the 301/651 Metrologging System to a computer in a way most beneficial

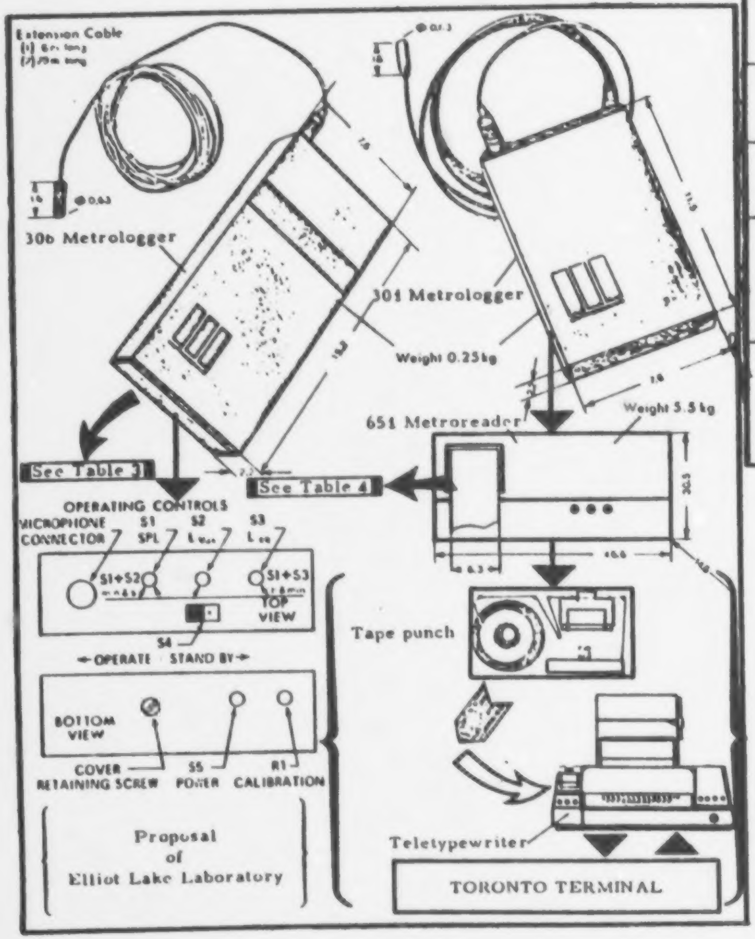

Extension Cable
(1) 6m long
(2) 25m long
306 Metrologger
301 Metrologger
Weight 0.25kg
Weight 5.5kg
651 Metroreader
See Table 3
See Table 4
OPERATING CONTROLS
MICROPHONE CONNECTOR
S1 SPL
S2 L max
S3 L eq
S1+S2
S1+S3
TOP VIEW
S4
← OPERATE STAND BY →
BOTTOM VIEW
COVER RETAINING SCREW
S5 POWER
R1 CALIBRATION
Proposal of Elliot Lake Laboratory
Tape punch
Teletypewriter
TORONTO TERMINAL

Fig. 6: Instrumentation for noise investigation in mines.

Table 3 - 306 Metrologger: program modules

Replacement	Dynamic Range	Provision	Sample Rate	Levels
PROM /14	40 to 103 dBA	Test duration and SPL over a measurement range	4/sec	L_{eq}^{+} L_{max} SPL
PROM /16	60 to 123 dBA	Test duration and SPL over a measurement range	4/sec	L_{eq}^{+} L_{max} SPL
PROM /26	60 to 123 dBA	Test duration and SPL over a measurement range	4/sec	L_{OSHA}^{*} L_{max} SPL
PROM /26-90	60 to 123 dBA	Test duration and SPL over a measurement range. The data below 90 dB will not be integrated into the L_{OSHA} memory.	4/sec	L_{OSHA}^{*} L_{max} SPL
PROM /26-85	60 to 123 dBA	Test duration and SPL over a measurement range. The data below 85 dB will not be integrated into the L_{OSHA} memory.	4/sec	L_{OSHA}^{*} L_{max} SPL

Table 4 - 301 Metrologger: program modules

Replacement	Dynamic Range	Provision	Sample Rate	Levels
PROM /14	40 to 103 dBA	Time History for 8 hours	4/sec	L_{eq}^{+}
PROM /16	60 to 123 dBA	Time History for 8 hours	4/sec	L_{eq}^{+}
PROM /25	60 to 123 dBA	Time History for 8 hours	4/sec	L_{OSHA}^{*}
PROM /34	40 to 103 dBA	Sample Distribution up to 100 hours	4/sec	L_n L_{eq}^{+} L_{OSHA}^{*} $L_{OSHA\,(85)}^{*}$ $L_{OSHA\,(90)}^{*}$
PROM /35	60 to 123 dBA	Sample Distribution up to 100 hours	4/sec	L_n L_{eq}^{+} L_{OSHA}^{*} $L_{OSHA\,(85)}^{*}$ $L_{OSHA\,(90)}^{*}$

NOTE: + 3 dB exchange rate
* 5dB exchange rate

to Canadian mines (Fig. 6). The results were excellent. With only one PROM it is possible to have all important data: current and cumulative L_{OSHA}, current and cumulative percent dose, min comp, max comp, arithmetic mean, std deviation, variance, amplitude distribution and time history profile (Fig. 7, 8 and 9). The following must be stressed:

1. On the day following the taking of measurements, the worker should be given a hard copy from the 651 Metroreader, and current, as well as cumulative, L_{OSHA}.
2. On the basis of 301 Metrologger's data, other statistical data can be obtained by changing computer programs.

New instruments are part of the procedure to obtain the full information required for the establishment of control programs for the mining environment, that is:

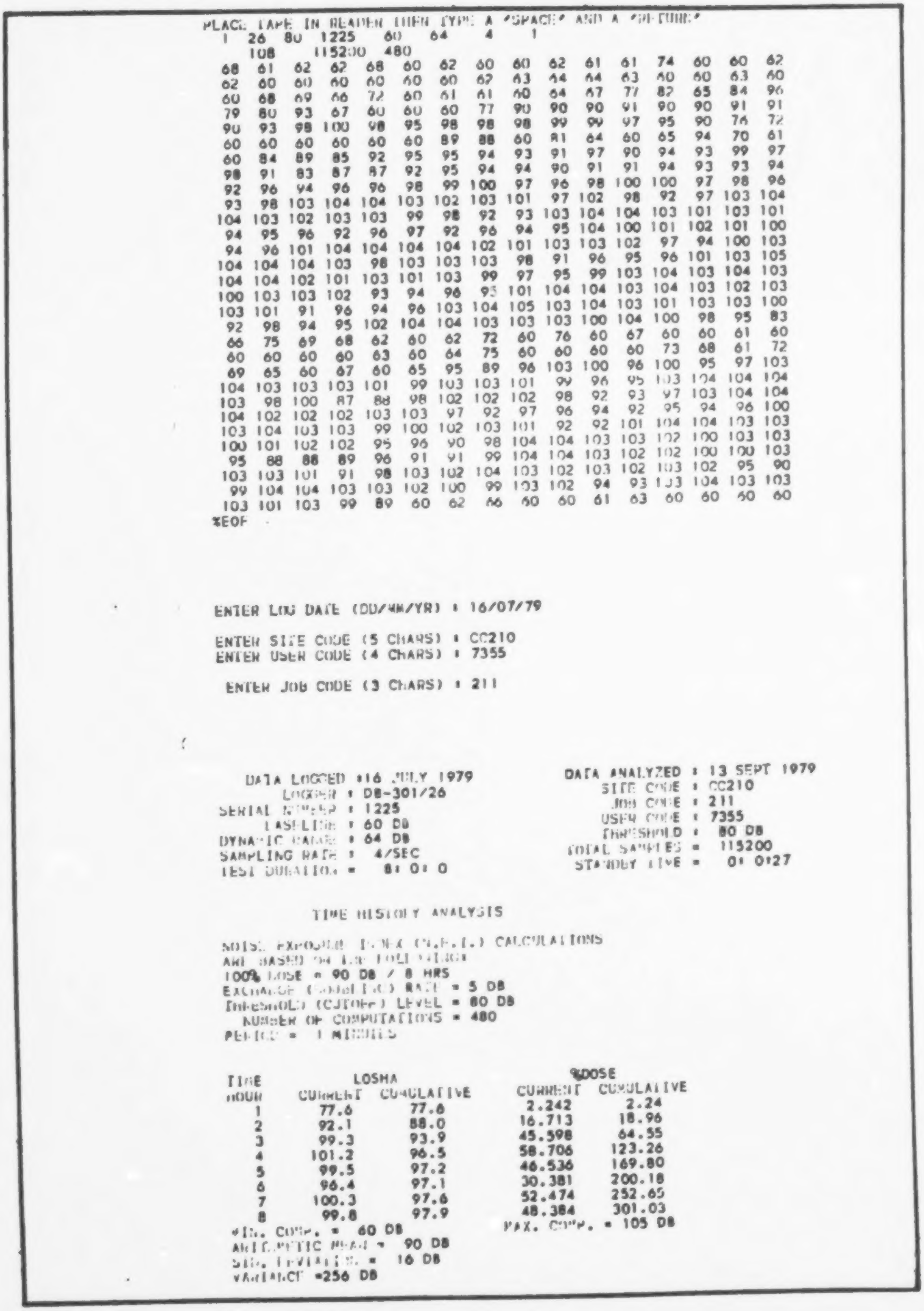
- noise measurement and assessment;
- identification of risk areas;
- noise control in the working environment; and
- control of protective equipment and reduction of exposure time.

These instruments cannot satisfy the requirement to register impulse numbers of impacts per work-day because instruments are not constructed in such a way.

The 301/651 Metrologging system is a significant advance in noise monitoring instrumentation. Proposed systems go so far as to enable a computer to write a technical printout with all necessary results.

3. CONCLUSION AND RECOMMENDATION

In the last ten years Canadian mines have made great advances in the field of noise abatement. Measurements have been taken to protect, as much as is possible, the miners' hearing. Measurements will eventually be



```
PLACE TAPE IN READER THEN TYPE A 'SPACE' AND A 'RETURN'
 1   26  80  1225    60    64     4     1
       108     115200   480
  68  61  62  62  68  60  62  60  60  62  61  61  74  60  60  62
  62  60  60  60  60  60  60  62  63  64  64  63  60  60  63  60
  60  68  69  66  72  60  61  61  60  64  67  77  82  65  84  96
  79  80  93  67  60  60  60  77  90  90  90  91  90  90  91  91
  90  93  98 100  98  95  98  98  98  99  99  97  95  90  76  72
  60  60  60  60  60  60  89  88  60  81  64  60  65  94  70  61
  60  84  89  85  92  95  95  94  93  91  97  90  94  93  99  97
  98  91  83  87  87  92  95  94  94  90  91  91  94  93  93  94
  92  96  94  96  96  98  99 100  97  96  98 100 100  97  98  96
  93  98 103 104 104 103 102 103 101  97 102  98  92  97 103 104
 104 103 102 103 103  99  98  92  93 103 104 104 103 101 103 101
  94  95  96  92  96  97  92  96  94  95 104 100 101 102 101 100
  94  96 101 104 104 104 104 102 101 103 103 102  97  94 100 103
 104 104 104 103  98 103 103 103  98  91  96  95  96 101 103 105
 104 104 102 101 103 101 103  99  97  95  99 103 104 103 104 103
 100 103 103 102  93  94  96  95 101 104 104 103 104 103 102 103
 103 101  91  96  94  96 103 104 105 103 104 103 101 103 103 100
  92  98  94  95 102 104 104 103 103 103 100 104 100  98  95  83
  66  75  69  68  62  60  62  72  60  76  60  67  60  60  61  60
  60  60  60  60  63  60  64  75  60  60  60  60  73  68  61  72
  69  65  60  67  60  65  95  89  96 103 100  96 100  95  97 103
 104 103 103 103 101  99 103 103 101  99  96  95 103 104 104 104
 103  98 100  87  88  98 102 102 102  98  92  93  97 103 104 104
 104 102 102 102 103 103  97  92  97  96  94  92  95  94  96 100
 103 104 103 103  99 100 102 103 101  92  92 101 104 104 103 103
 100 101 102 102  95  96  90  98 104 104 103 103 102 100 103 103
  95  88  88  89  96  91  91  99 104 104 103 102 102 100 100 103
 103 103 101  91  98 103 102 104 103 102 103 102 103 102  95  90
  99 104 104 103 103 102 100  99 103 102  94  93 103 104 103 103
 103 101 103  99  89  60  62  66  60  60  61  63  60  60  60  60
%EOF


ENTER LOG DATE (DD/MM/YR) : 16/07/79

ENTER SITE CODE (5 CHARS) : CC210
ENTER USER CODE (4 CHARS) : 7355

 ENTER JOB CODE (3 CHARS) : 211



   DATA LOGGED :16 JULY 1979              DATA ANALYZED : 13 SEPT 1979
        LOGGER : DB-301/26                    SITE CODE : CC210
 SERIAL NUMBER : 1225                          JOB CODE : 211
      BASELINE : 60 DB                        USER CODE : 7355
 DYNAMIC RANGE : 64 DB                        THRESHOLD :  80 DB
 SAMPLING RATE :  4/SEC                   TOTAL SAMPLES =  115200
 TEST DURATION =   8: 0: 0                 STANDBY TIME =   0: 0:27

           TIME HISTORY ANALYSIS

 NOISE EXPOSURE INDEX (N.E.I.) CALCULATIONS
 ARE BASED ON THE FOLLOWING
 100% DOSE = 90 DB / 8 HRS
 EXCHANGE (DOUBLING) RATE = 5 DB
 THRESHOLD (CUTOFF) LEVEL = 80 DB
   NUMBER OF COMPUTATIONS = 480
 PERIOD =  1 MINUTES

 TIME            LOSHA                        %DOSE
 HOUR     CURRENT  CUMULATIVE        CURRENT  CUMULATIVE
   1        77.6       77.6            2.242       2.24
   2        92.1       88.0           16.713      18.96
   3        99.3       93.9           45.598      64.55
   4       101.2       96.5           58.706     123.26
   5        99.5       97.2           46.536     169.80
   6        96.4       97.1           30.381     200.18
   7       100.3       97.6           52.474     252.65
   8        99.8       97.9           48.384     301.03
  MIN. COMP. =  60 DB              MAX. COMP. = 105 DB
  ARITHMETIC MEAN =  90 DB
  STD. DEVIATION =  16 DB
  VARIANCE =256 DB
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Fig. 7: Data from the 651 Metroreader and computer.

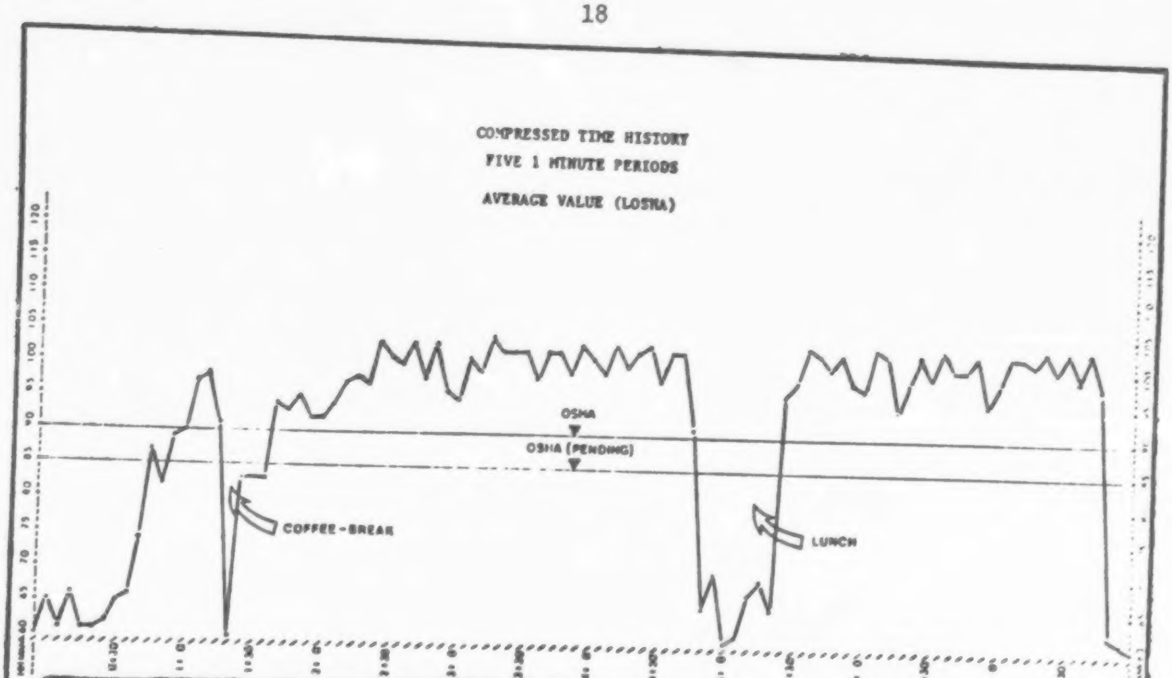

Fig. 9: Time history profile during shift.

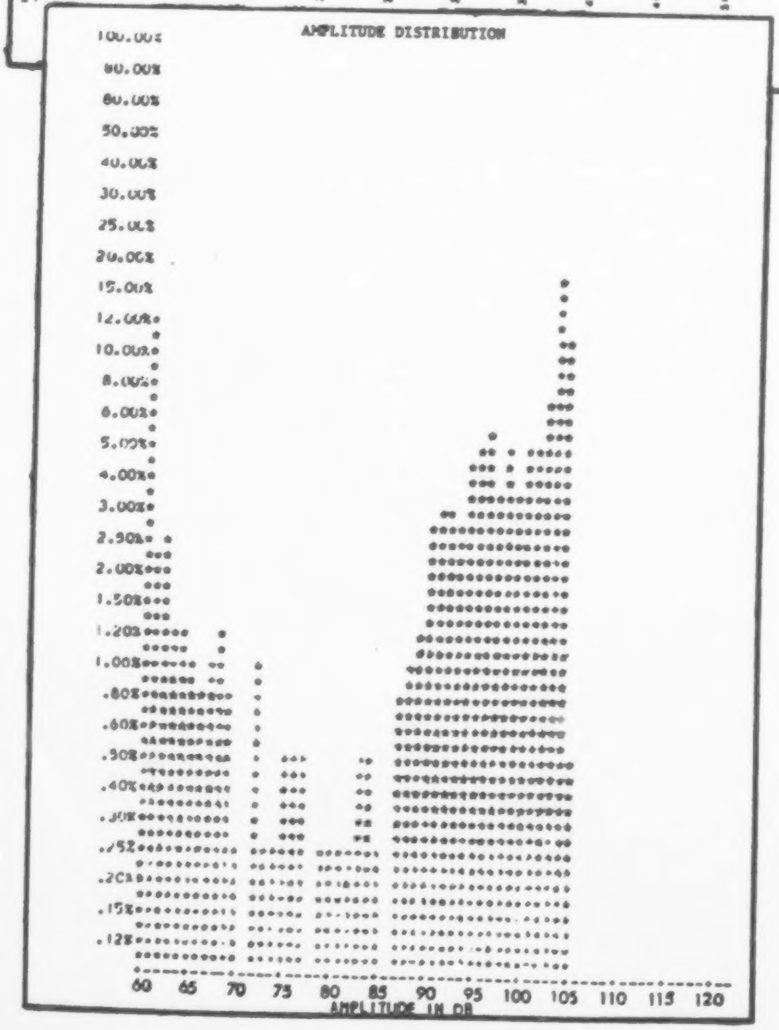

Fig. 8: Amplitude distribution during shift.

completely automated and plugged into a computer system. It follows that audiometric tests will take the same route.

The Workmen's Compensation Board will have exact data; and, upon implementation of a new computer program, they will have the capability tc correctly judge each claim.

Management will have great use for this, since they will be able to follow up on maintenance, work efficiency and protection. Also, the closer union between workers and management has important and beneficial economic and social repercussions.

CANMET, E.M.R., has taken measures to install a new generation of instruments into helmets and to automate measurements. It will not end there. New development and production of very high speed integrated circuits (VHSIC) with higher speficications, such as humidity resistance and temperature tolerance, will improve the speed, reliability and capability of electronic equipment (7).

The noise dosimeter will be developed smaller and lighter, and its applications will multiply in number.

4. ACKNOWLEDGEMENTS

The author wishes to thank all of the mines that have supported the Elliot Lake Laboratory, and the many colleagues in the mines and the Elliot Lake Laboratory involved.

Thanks are also extended to Dr. P.W. Alberti, Professor of Otolaryngology and Occupational and Environmental Medicine, University of Toronto for granting the opportunity to prepare this paper, and R. Tervo, Manager, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada for helpful suggestions.

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Noise measurement in Mines

1980

Presented International Symposium

on Hearing Protection, Toronto, May 1980

MESURE DU BRUIT DANS LES MINES DE LA DENISON MINES LTÉE À ELLIOT LAKE

par

M.U. Savich*

RÉSUMÉ

Les objectifs de la mesure du bruit dans les mines de la Denison Mines Ltée sont les suivants :

1) Examiner la nouvelle génération de dosimètres de bruit utilisés pour mesurer l'indice d'exposition au bruit
2) Rapprocher la Direction et le syndicat en ce qui concerne l'évaluation des problèmes environnementaux associés au bruit.

Ces mesures visent à résoudre les problèmes suivants :

1) sécurité des travailleurs
2) santé des travailleurs
3) conséquences environnementales
4) productivité.

Le système met en évidence le rôle important du programme informatisé fondé sur le calcul total pendant le poste de travail (8 h = 480 min) avec moyennage toutes les minutes de L_{OSHA}. On peut ainsi obtenir des données complètes : variation en fonction du temps (numérique), code du site, code de la

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tâche, code de l'utilisateur, nombre de calculs (temps), L_{OSHA} (courant et cumulatif), dose en pourcentage (courante et cumulative), calcul de minimums, calcul de maximums, moyenne arithmétique, écart-type, variance, distribution de l'amplitude (numérique et graphique) et variation en fonction du temps (graphique).

Cette méthode de mesure a été utilisée pour la première fois dans les mines de la Denison Mines Ltée.

NOISE MEASUREMENT AT DENISON MINES LTD. IN ELLIOT LAKE

by

M.U. Savich*

ABSTRACT

Noise measurement at Denison Mines Ltd. is directed towards the following objectives:

1) To examine the new generation of noise dosimeters, utilized in measuring the noise exposure index (NEI); and
2) To bring closer the opinions of management and the union in matters relating to the assessment of environmental problems resulting from noise.

This system of measurement contributes to the solution of the following problems:

1) worker safety;
2) worker health;
3) environmental impact; and
4) productivity.

The system exemplifies the important role of the computer program based on the total computations of shift time (8 h = 480 min) averaging every one minute L_{OSHA}. Full information can be obtained: time history (numerical), site code, job code, user code, number of computations (time), L_{OSHA} (current and cumulative) percent dose (current and cumulative), minimum computations, maximum computations, arithmetic mean, standard deviation, variance, amplitude distribution (numerical and graphical) and time history (graphical).

This method of measurement was performed for the first time ever at Denison Mines Ltd.

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* Research Scientist, Elliot Lake Laboratory, Mining Research Laboratories, Canada Centre for Mineral and Energy Technology, Department of Energy, Mines and Resources, Elliot Lake, Ontario.

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INTRODUCTION

The Noise Exposure Index (NEI) measurement program is being conducted by the Elliot Lake Laboratory, CANMET, in local mines. Discussions with Denison Mines Ltd. indicated a common interest in assessing noise.

The task of industrial noise control and hearing conservation programs is to protect employees from permanent hearing loss in the speech frequency range. Noise measurement at Denison Mines Ltd. is directed towards the following objectives:

1) To examine the relative contribution of the new generation of noise dosimeters, utilized in measuring the noise exposure index (NEI);
2) To bring closer the opinions of management and the union in matters relating to the assessment of environmental problems resulting from noise.
3) To find a method of immediately informing the worker of the hazard, and to make all efforts possible to remove the hazard.

The scope of this report is to fully describe the NEI: L_{OSHA}, percent dose, minimum and maximum computations, amplitude distribution and time history will be explained. Data presented in this manner are useful to workers, the management and the compensation board.

HEARING LOSS FROM NOISE EXPOSURE

Occupational deafness is irreversible hearing loss (the permanent threshold shift - PTS). Hearing loss for a given sound is the difference in decibels between the hearing threshold for that sound and the threshold of hearing. Audiometric testing of miners who have been subjected to prolonged exposure to high noise levels will reveal enfeeblement of hearing acuity in the higher frequency ranges between 3000 and 6000 Hz (Fig. 1)(1).

A noise-induced hearing loss initially damages the sensitive hair

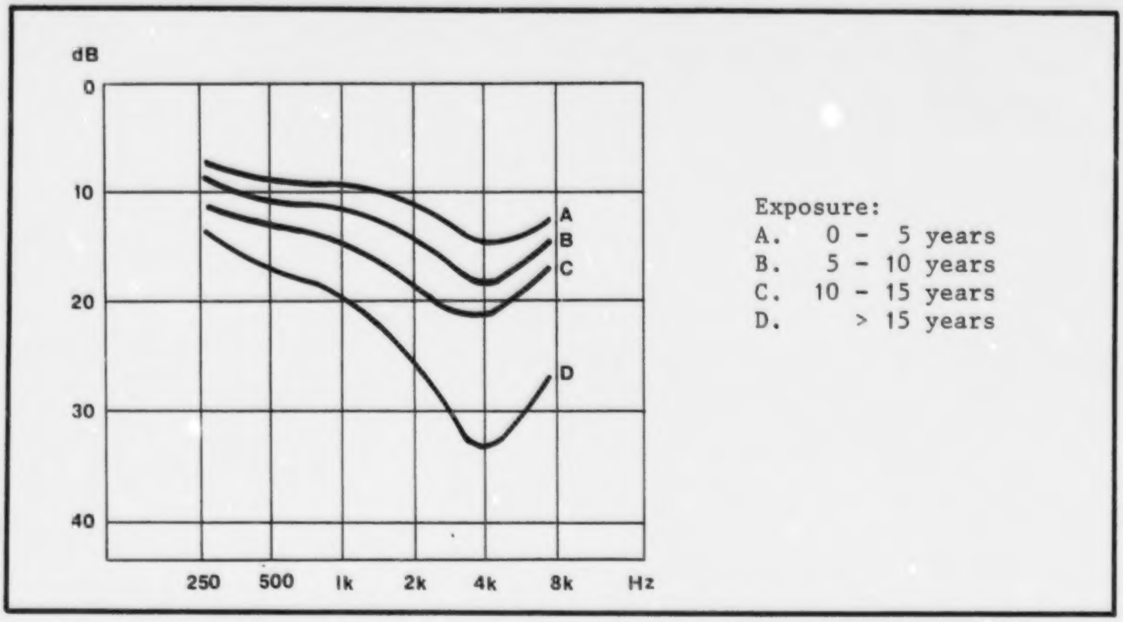

Fig. 1: Mean audiogram of employees exposed to industrial noise (1).

cells in the organ of the Corti, causing a loss of acuity at 4000 Hz. If a person's ability to hear conversational speech has not been affected, the hearing loss goes undetected in its temporary stage (the temporary threshold shift - TTS). These two types of hearing loss have many graduations between them. In evaluating noise-induced hearing loss, the PTS should be measured after recovery of TTS, and PTS should be measured after termination of exposure, or before work commences.

A noise-induced hearing loss generally affects both ears in persons under 40 years of age. Some individuals seem more sensitive to loud sound than others (2). When examining the hearing of a mining or industrial community, the various non-occupational causes of hearing loss, in particular infection, during intoxication and presbycusis, should be kept in mind.

HEARING LOSS CRITERIA

Mining (industrial) noises are a complex mixture of several notes having their individual frequencies, intensities, and distribution in time.

The different types of noise are:

a) continual wide-band noise, i.e., noise including a wide range of frequencies, e.g., general mining or machine shop noise;

b) continual narrow-band noise, i.e., the sound energy is concentrated in a few frequencies, e.g., drill hammers and circular saws;

c) impact or impulse noise, i.e., short duration impulses, e.g., tapping and hammering (the noise is a change in sound pressure level of 40 dB or more within 0.5 seconds);

d) steady-state (continuous) repeated impact noise where a change in sound pressure level is less than 40 dB between successive 0.5 second intervals, e.g., rivetting and breaking;

e) intermittent noise where there are several periods of steady-state noise with intervals of ambient noise, e.g., traffic and drilling noise.

Using time and level as the measure, there are four classes into which occupational noise exposures may be grouped:

1) long-term continuous noise,
2) short-term continuous noise,
3) intermittent equal-intensity noise, and
4) intermittent variable-intensity noise.

Long term continuous noise is defined as noise of a constant level and spectrum to which a listener is exposed for 6 to 8 hours per day, 40 hours per week, 50 weeks per year. Most criteria are written for this type of operator exposure noise.

Short-term continuous noise is defined as broad-band noise at a constant level for less than 5 hours per day, 5 days per week, for life. The octave bands 500, 1000, and 2000 Hz are considered, because these bands are of importance in the protection of hearing for speech.

Intermittent variable noise is defined as broad-band noise which is intermittent in time duration and variable in both duration of "on" and "off" time and absolute magnitude. This is the most common noise in a mining and metallurgical environment.

Sataloff, Vassallo, and Mendulse (3) found that underground iron ore miners exposed intermittently to intense rock drill noise showed no greater hearing damage than do mill workers exposed to steady noise 20 dB lower. Other reports of hearing damage to miners agree with Sataloff et al. (3,4).

STANDARDS FOR OCCUPATIONAL NOISE EXPOSURE

Standards for occupational noise exposure are not uniform in Canada. British Columbia uses criterion ISO*R 1999 Assessment of Occupational Noise Exposure for Hearing Conservation purposes. The United States and other parts of Canada use a slightly different criterion from Occupational Safety and Health (OSHA). Both criteria prescribe a maximum continuous exposure level of 90 dBA in the work environment (Table 1). Below 90 dBA, ISO controls exposures down to 80 dBA. OSHA sets no limits below 90 dBA, but a proposal is pending to extend control by lowering it to 85 dBA. Table 1 shows that allowable exposure time is halved for each 3 dBA increase in noise level under ISO and for each 5 dBA increase under OSHA. The 3 and 5 dBA interval is called the "trading ratio" or the "q" (coefficient) in the equation.

These two criteria also differ in how they block out work periods. ISO permits averaging exposure over a 40 hour work week, but OSHA permits averaging over just an 8-hour work day.

Criteria for assessing hearing loss risk due to impulsive noise are not broadly standardized. OSHA maximum allowable level is 140 dB peak sound pressure level for up to 100 impulses per day, with a 10 dB decrease in allowable

---

* International Organization for Standardization.

Table 1 - Threshold limit values continuous or intermittent noise ISO and OSHA

		ISO Noise Dose %	dBA	OSHA Max Time h-min	
8 h		10	80		
		15	82		
		20	83		
		25	84		
		30	85	16-0	Pending
		40	86	13-36	
		50	87	12-8	
		60	88	10-34	
		80	89	9-11	
	q = 3	100	90	8-0	
		125	91	6-56	q = 5
		160	92	6-4	
		200	93	5-17	
		250	94	4-36	
		315	95	4-0	
		400	96	3-29	
		500	97	3-2	
		630	98	2-50	
		800	99	2-15	
		1000	100	2-0	
		1250	101	1-44	
		1600	102	1-31	
		2000	103	1-19	
		2500	104	1-9	
		3150	105	1-0	
		4000	106	0-52	
		5000	107	0-46	
		6300	108	0-40	
		8000	109	0-34	
		10000	110	0-30	
		12500	111	0-26	
		16000	112	0-23	
		20000	113	0-20	
		25000	114	0-17	
		31500	115*	0-15	

* No exposure to continuous or intermittent excess of 115 dBA.

Note: Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level (OSHA).

level for each factor of 10 increases in the number of impulses.

To determine noise exposure index and equivalent continuous sound level, the numerical value of parameter q and the varying sound level p(t) within the considered time period T should be evaluated. L_{eq} is defined mathematically by (5):

$$L_{eq} = \frac{q}{\log_{10}2} \log \left[\frac{1}{T} \int_{o}^{T} \left(\frac{p(t)}{p_o} \right)^{\frac{20 \log_{10}2}{q}} dt \right] \qquad \text{Eq 1}$$

where q has different values:

	q	$\frac{q}{\log_{10}2}$	$\frac{20 \log_{10}2}{2}$
OSHA	5	16.61	1.20
ISO	3	9.97	2.01

T is the total sampling period in hours;

p(t) is the instantaneous A-weighted sound pressure in Pa (pascal);

p_o is the reference r.m.s. sound pressure, 2×10^{-5} Pa; and

t is the time in hours.

When the noise consists of different dBA noise levels throughout the day, the combined exposure is controlled by calculating from Table 1.

INSTRUMENTS

All noise dosimeter manufacturers made an effort to have their instruments meet existing regulations and to give the final result: Noise Exposure Index (NEI). Metrosonics Instruments, however, provided more useful data than those previously obtained on other dosimeters.

306 METROLOGGER

The 306 Metrologger digital sound level analyzer is a pocket-size computer designed for automatic sound level analysis over a selected 64 dB range. The internal computer circuit samples the amplitude, calculates and provides 4 digit displays of SPL, L_{max}, L_{eq} or L_{OSHA}, and the time duration of the sampling period. The samples are converted to digital format and stored. The 306 analyzer samples the detected amplitude level 4 times per second. Test duration can be from one second to 252, 750 seconds or 70.2 hours (252, 750.25 x 4 = 1,011,001). The PROM (Program Modules) replacement feature provides the ability to change the functions of the 306 Metrologger.

301/651 METROLOGGING SYSTEM

The 301 Metrologger is designed for processing and storing sound level information. The 651 Metroreader is a desk analyzer with an internal printer. The 651 reader interrogates the 301's memories (similar to 306 Metrologger) and calculates important noise data, including time history profiles, amplitude distribution, histograms, computations of L_{eq}, L_{OSHA}, exposure coefficient criteria etc. A variety of PROM (Program Modules) in the program library make the Metrologger multi-functional.

THE ACCURACY OF INSTRUMENTS

The accuracy of noise dose measured with dosimeters complying with ANSI Standard S1.25-1978 has been questioned because of the presence of impulsive wave forms (6). The errors are to be expected since dosimeters have limited crest factor capabilities. The averaging of SPL with a 3 dB exchange (trading) ratio is dependent on the wave form and the averaging time. J.J. Earshen has shown that (6):

> "Dosimeters complying with ANSI S1.25 and using 5dB exchange ratio are intrinsically susceptible to noise dose overestimation in the presence of impulsive noise..... In the final analysis, specialists who formulate hearing damage risk criteria must be fully appraised of instrument measurement capabilities and idiosyncrasies of proposed dosimeter standards."

G. Rasmussen disagrees and believes that the construction of dosimeters with a 3 dB exchange ratio is necessary (7). The data obtained can be mathematically or electronically converted to 5 dB exchange ratio values. The 301/651 Metrologging system is ideal for bringing this into reality. A computer program can convert noise measured with PROM for 3 dB exchange ratio to values for 5 dB exchange ratio (OSHA). The value of the results would be even greater since they enable specialists who formulate hearing damage risk criteria to evaluate both standards. Error with 3 dB exchange ratio would very likely be small.

It must again be stressed that it is possible to mathematically and electronically convert ISO values (3 dB exchange ratio to OSHA values 5 dB exchange ratio). The converse is not possible either mathematically or electronically.

MEASUREMENTS

Measurement of Noise Exposure Index was conducted with fifteen 301 Metrologger instruments. Theoretically 825 measurements should have been taken, however, due to equipment breakdown, 610 (73.94%) were actually conducted. Of these 610 measurements, 108 (17.7%) were rejected for the following reasons:

Error 1* (logger not sending)	78
Error 2 (301 PROM not available)	1
Error 12 (division error)	16
Short logging time	5
Lost or damaged microphone	4
Broken cable	4
	108

Alligator clamps for the microphones were lost or kept by the labour force as souvenirs.

Total efficiency of the instruments during all measurement was 60.8%; this is relatively low.

These instruments cannot satisfy the requirement to register impulse numbers of impacts per work-day because instruments are not constructed in such a way.

---

*Consists of 48% human error due to improper design of ON/OFF switch on the instruments.

The 301/651 Metrologging system is a significant advance in noise monitoring instrumentation. Proposed systems go so far as to enable a computer to write a technical printout with all necessary results.

EXPLANATION OF THE NOISE DOSIMETER SURVEY

Denison staff informed the workers and the Union about the measuring of NEI in the mine (Appendix 1). The intent was to acquaint the workers and Union with the manner in which measurements are taken and the objectives of these measurements. The aims of the noise exposure index measurements are outlined in Fig. 2 under two general headings:

1) Partial information of NEI measurement for the worker, Union and safety office; and
2) Full information of NEI measurement for management, Union and environment office directly and for government agencies and compensation board indirectly.

Tests were carried out at the following sites:

- crushing plant;
- grinding plant;
- hydrometallurgical plant;
- assay laboratory;
- maintenance (surface);
- underground Shaft No. 1; and
- underground Shaft No. 2;

Underground maintenance not performed.

Partial Information

At the beginning of the shift the 301 Metrologger (noise dosimeter) was given to the worker. The microphone was clamped onto the rim of the hat or on the collar. The noise survey form was filled in with pertinent information

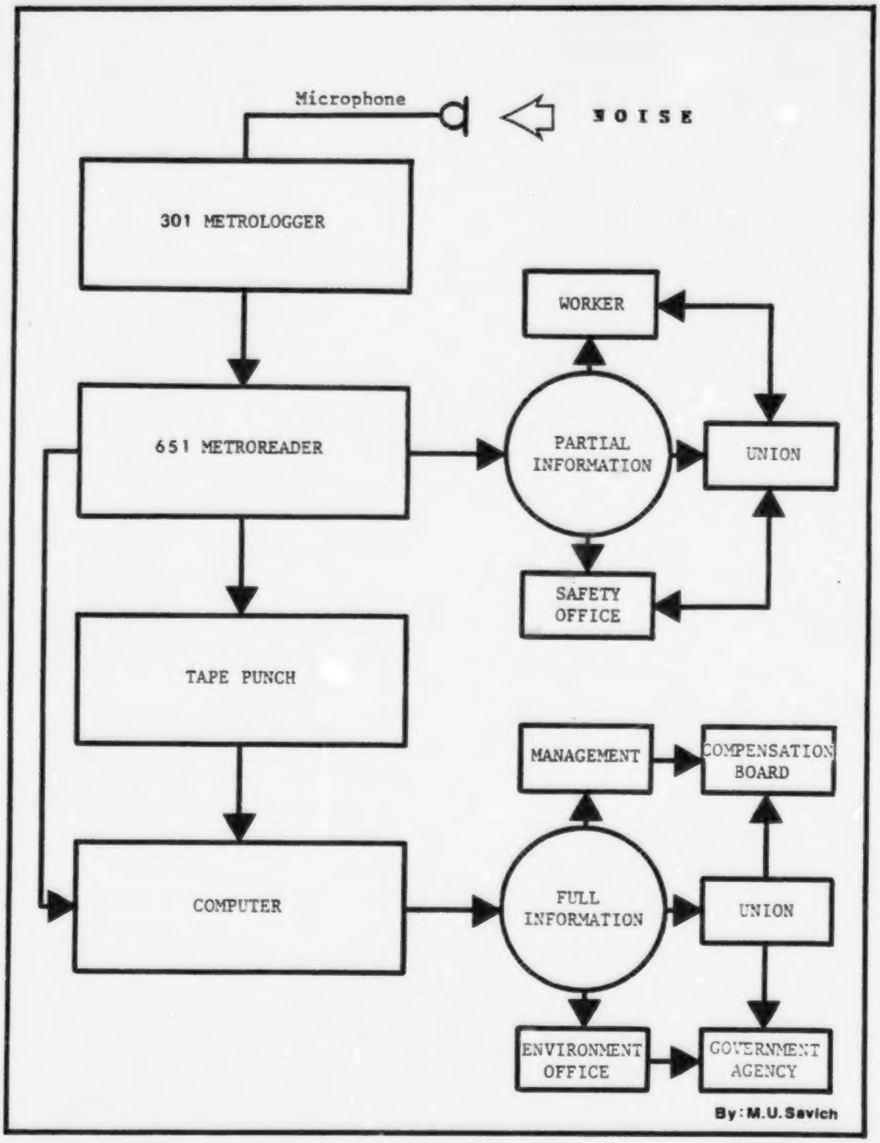
Microphone
NOISE
301 METROLOGGER
651 METROREADER
TAPE PUNCH
COMPUTER
WORKER
PARTIAL INFORMATION
UNION
SAFETY OFFICE
MANAGEMENT
COMPENSATION BOARD
FULL INFORMATION
UNION
ENVIRONMENT OFFICE
GOVERNMENT AGENCY
By: M.U.Savich

Fig. 2: Flow sheet diagram of Noise Exposure Index test procedure.

on the worker: name, payroll number, occupation, location, etc., (Appendix 2). After the shift the 301 Metrologger is connected to a 651 Metroreader which provides the first hard copy of current and cumulative L_{OSHA} results. The following day the worker, in this case welder P. Gratton, receives the information. On the basis of this information he can evaluate the necessity of personal protection, and discuss this with co-workers and the Union (Appendix 3). The safety office can supply the necessary equipment and give advice on ear protection.

Full Information

The Metroreader was connected by the interface to the Facit tape punch machine or directly to the computer depending on needs and circumstances. Based on the total computations of shift time (8 h = 480 min) averaging every one minute L_{OSHA} and on the computer program, full information can be obtained (Fig. 2): time history (numerical); site code, job code, user code, number of computations (time), L_{OSHA} (current and cumulative) percent dose (current and cumulative), minimum computations, maximum computations, arithmetic mean, standard deviation, variance,amplitude distribution (numerical and graphical) and time history (graphical).

Appendix 6 gives detailed record of noise exposure index and other data of welder P. Gratton. These data can be used for administrative and engineering control of noise and control of work productivity.

The environmental office has all the necessary data to enable it to set guidelines, and, in cooperation with the Union, can reach correct and acceptable conclusions. How much degradation of pneumatic machine noise is there and by how much is LHD noise increased, is a question always posed (8). In this case, we have definitive data regarding the increase of noise in mines (or the decrease of noise, if proper protective measures have been taken).

Current existing data are very scant and inadequate to produce results with any degree of confidence. The target noise levels vary over the time periods according to a probability distribution. The Union has an opportunity to examine all problems very closely. On the basis of these measurements correct and acceptable conclusions are possible. Management and the Union have a hard copy from which they can conclude whether or not the claimant is justified in going to the Workmen's Compensation Board.

Canada pays out millions and will be paying out millions of dollars more for employees' job-related hearing losses. Safety rules have been disregarded and disciplinary action lacking (8).

In the first half of the last decade new mechanization was introduced in Canadian underground mines. This mechanization, with the same labour force, enabled productivity to remain at the same level despite low grade ore (9). The productivity trend in the last half of the decade was likely the same. Because Canada's share of the world market has declined, we must first increase productivity in present mines. Full information of noise exposure measurements can help in this effort.

From Fig. 3 it can be seen that the truck driver was 40 min late for work at the beginning of the shift. Normally, this would be 10 or 15 min as is the case at the end of the shift. Another interesting example is found in Appendix 6. The time history graph demands serious analysis. Before lunch the plant was not operational due to maintenance work. Periodically some machines were operating. During lunch at 4.30 the lunch room door was open for 15 min. In the afternoon the worker had two breaks.

Management can be satisfied since it has a picture of the movement and work of welder P. Gratton. The environment office will order that an automatic shutting device be installed on the lunch room. When the plant is

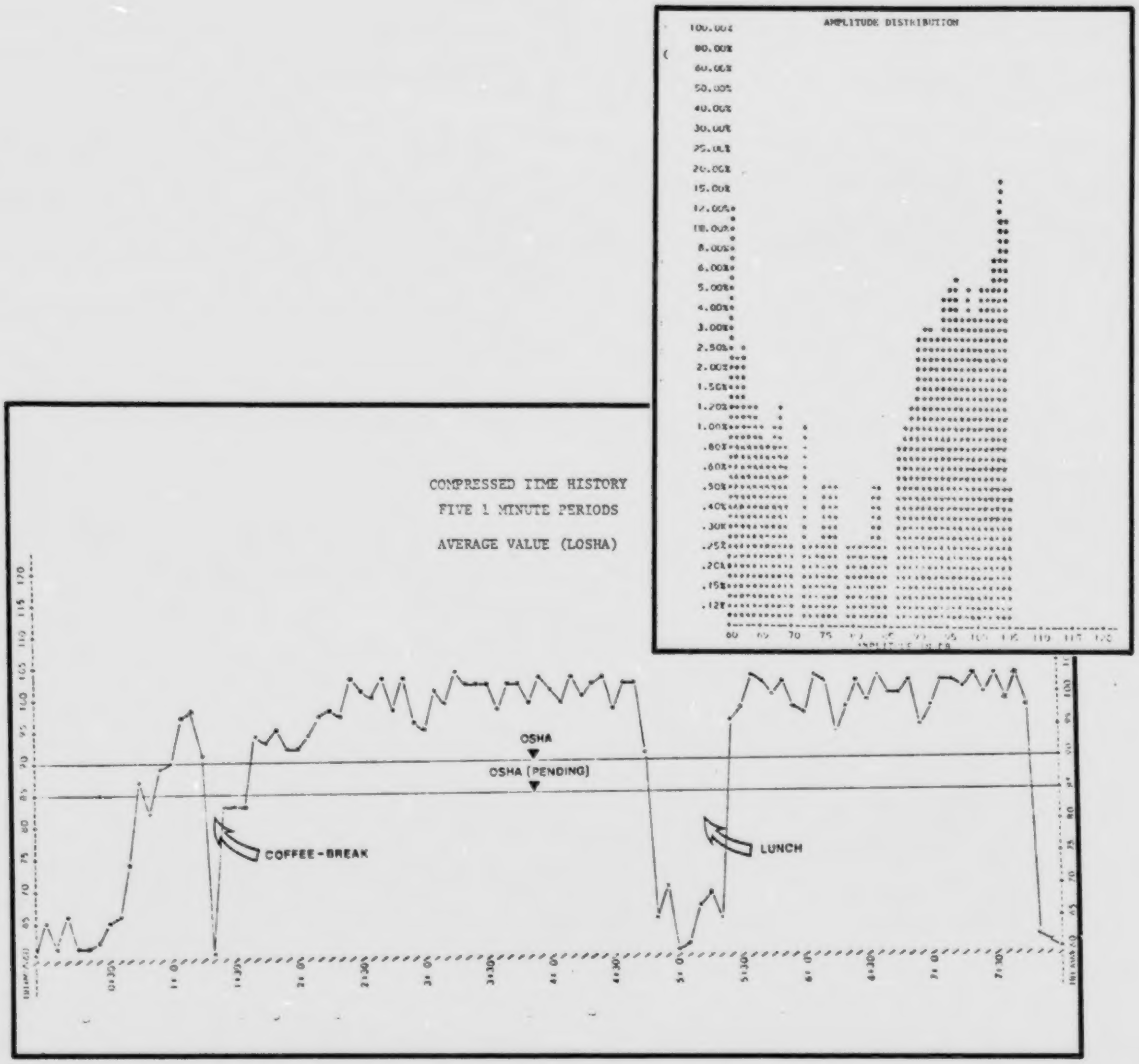

Fig. 3: Truck drivers' time history and amplitude distribution graph.

fully operational welder P. Gratton will be over-exposed.

The environment office will be occupied with the problem of what should be done and how to protect welders in the crushing plant. The Union will be satisfied because self-protection and responsibility among workers will be encouraged and management must act in accordance with the guidelines to protect workers.

The system has a twofold purpose:

1) to protect the hearing of the worker; and

2) to increase productivity.

The environmental office takes on the role of an operative unit and loses its bureaucratic character.

Program for 301/651 Metrologging System

The program provides analysis of 301 data sets that have been transferred to paper tape from a dB-651 (Appendix 1 (10)). A special PROM set must be installed in the dB-651 to transfer the data to paper tape.

The program prompts the operator with instructions for use. There is no optional input allowed to specify the date, site, user, and job to be included in the printed report. Time history and amplitude distribution programs can both be processed. Multiple data sets can be analyzed; a report is printed for each set.

After initial set-up, the data is read from the tape. Header information is read and interpreted to determine the format of the remaining data. Time history programs have 480 data values which are the interval computation values. Distribution programs have 64 bin values which are the number of readings taken at each level.

A header is printed for each data set. Also printed, is an expanded amplitude distribution to show the lower percentage values in more detail.

Time history program calculates the percent DOSE and $L_{OSHA}(90)$ for each hour of testing. Arithmetic mean, standard deviation, and variance are computed from the data set and printed. A compressed time history is plotted with averaged values for LOSHA.

Appendix 4 gives the complete computer program for full information. For statistical analysis an additional program for numerical amplitude distribution was made (Appendix 5). These two programs will be integrated into one in the future.

CONCLUSIONS AND RECOMMENDATIONS

Special attenuation is commanded by two extreme conditions, usually referred to as "safety" and "productivity". The model provides a reasonable explanation and full information of NEI, but generally these should be used by workers, the Union, the safety and environment offices and the management in order to provide a safe working environment and increase productivity. This method of measurement was performed for the first time ever at Denison Mines Ltd. in cooperation with the Elliot Lake Laboratory.

One major contribution of this research is a demonstration of collection of more pertinent noise data with the second generation noise dosimeter. Measurement will be greatly simplified if the 301 Metrologger is built into the hat (11,12).

This method **exemplified** the important role of the computer program. In the future a program should be designed retaining criteria (step 3 dB to 5 dB). This system of measurement contributes to the solution of the following problems:

1) worker safety;
2) worker health;
3) environmental impact;
4) productivity.

Denison Mines Ltd. belongs to the group of mines which readily accepts new methods in exploration and protection. "The management will have great use for this, since they will be able to follow up on work efficiency, maintenance and production. Also, the closer union between workers and management has important and beneficial economic and social repercussions" (13).

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to A. Rickaby, General Manager and G. Stenning, Chief Mine Engineer, Denison Mines Ltd., Elliot Lake for their approval for conducting this survey and for purchasing instruments. J.L. Chakravatti, Sr. Environmental Engineer and B.Z. Zeljeznak, Environmental Engineer, Denison Mine, Elliot Lake were helpful in many ways. J.L. Chakravatti suggested that audiometric tests could be combined with measurements and data of NEI by a computer system. This idea remains to be carried through into reality.

Gratitude is extended to A.L. Stolberg, President and F.D. Carter III, Sr. Programmer, Metrosonics Inc., Rochester, New York for their cooperation in the development of the computer program. B. Brownlee, Manager, L_{eq} Measurement Ltd., Mississauga, Ontario contributed to the rapid solution of technical problems.

Grateful acknowledgement is extended to W.S. Bowman, Research Scientist, CANMET, Ottawa for the additional computer program and H. Poliquin, Sr. Technician, Elliot Lake Laboratory for work on the terminal and in the Laboratory. Students P.A. Davis, Guelph University and C. Larocque, Western University were also helpful.

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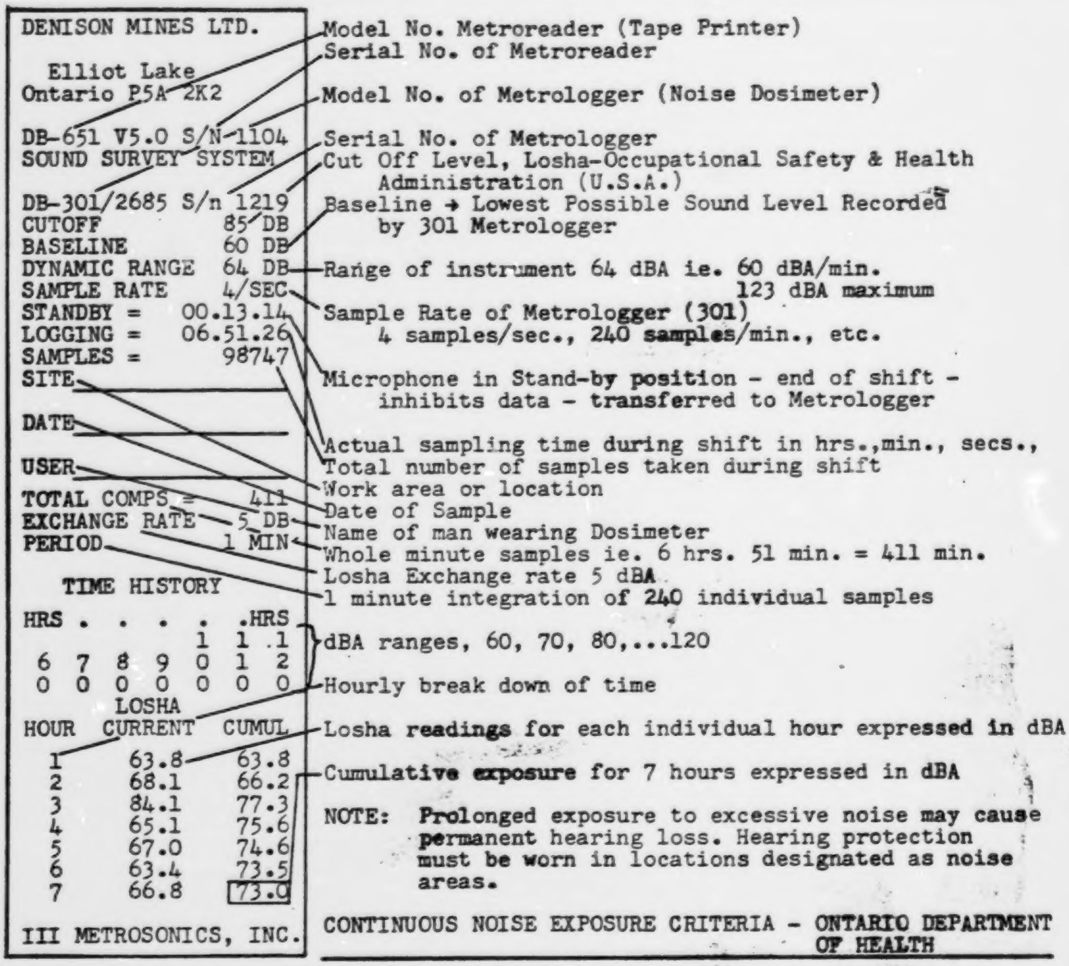
DENISON MINES LIMITED

Elliot Lake, Ont.

EXPLANATION OF THE NOISE DOSIMETER SURVEY



```
DENISON MINES LTD.

  Elliot Lake
Ontario P5A 2K2

DB-651 V5.0 S/N 1104
SOUND SURVEY SYSTEM

DB-301/2685 S/n 1219
CUTOFF             85 DB
BASELINE           60 DB
DYNAMIC RANGE      64 DB
SAMPLE RATE       4/SEC
STANDBY =      00.13.14
LOGGING =      06.51.26
SAMPLES =         98747
SITE ___________________

DATE ___________________

USER ___________________
TOTAL COMPS =       411
EXCHANGE RATE      5 DB
PERIOD            1 MIN

   TIME HISTORY

HRS .  .  .  .  . HRS
                1  1 .1
 6  7  8  9  0  1  2
 0  0  0  0  0  0  0
       LOSHA
HOUR  CURRENT   CUMUL
 1      63.8     63.8
 2      68.1     66.2
 3      84.1     77.3
 4      65.1     75.6
 5      67.0     74.6
 6      63.4     73.5
 7      66.8    [73.0]

III METROSONICS, INC.
```

Model No. Metroreader (Tape Printer)
Serial No. of Metroreader
Model No. of Metrologger (Noise Dosimeter)
Serial No. of Metrologger
Cut Off Level, Losha-Occupational Safety & Health Administration (U.S.A.)
Baseline → Lowest Possible Sound Level Recorded by 301 Metrologger
Range of instrument 64 dBA ie. 60 dBA/min. 123 dBA maximum
Sample Rate of Metrologger (301) 4 samples/sec., 240 samples/min., etc.
Microphone in Stand-by position - end of shift - inhibits data - transferred to Metrologger
Actual sampling time during shift in hrs.,min., secs.,
Total number of samples taken during shift
Work area or location
Date of Sample
Name of man wearing Dosimeter
Whole minute samples ie. 6 hrs. 51 min. = 411 min.
Losha Exchange rate 5 dBA
1 minute integration of 240 individual samples
dBA ranges, 60, 70, 80,...120
Hourly break down of time
Losha **readings** for each individual hour **expressed in** dBA
Cumulative exposure for 7 hours expressed in **dBA**

NOTE: **Prolonged** exposure to excessive noise **may cause permanent** hearing loss. Hearing protection **must be worn** in locations designated as **noise** areas.

CONTINUOUS NOISE EXPOSURE CRITERIA - **ONTARIO DEPARTMENT OF HEALTH**

90 dBA - 8 hours
95 dBA - 4 hours
100 dBA - 2 hours
105 dBA - 1 hour
110 dBA - ½ hour
115 dBA - ¼ hour

WEAR YOUR EAR PLUGS: THEY WILL LOWER YOUR EXPOSURE **TO NOISE** BY 15 - 25 **dBA**

Appendix 2

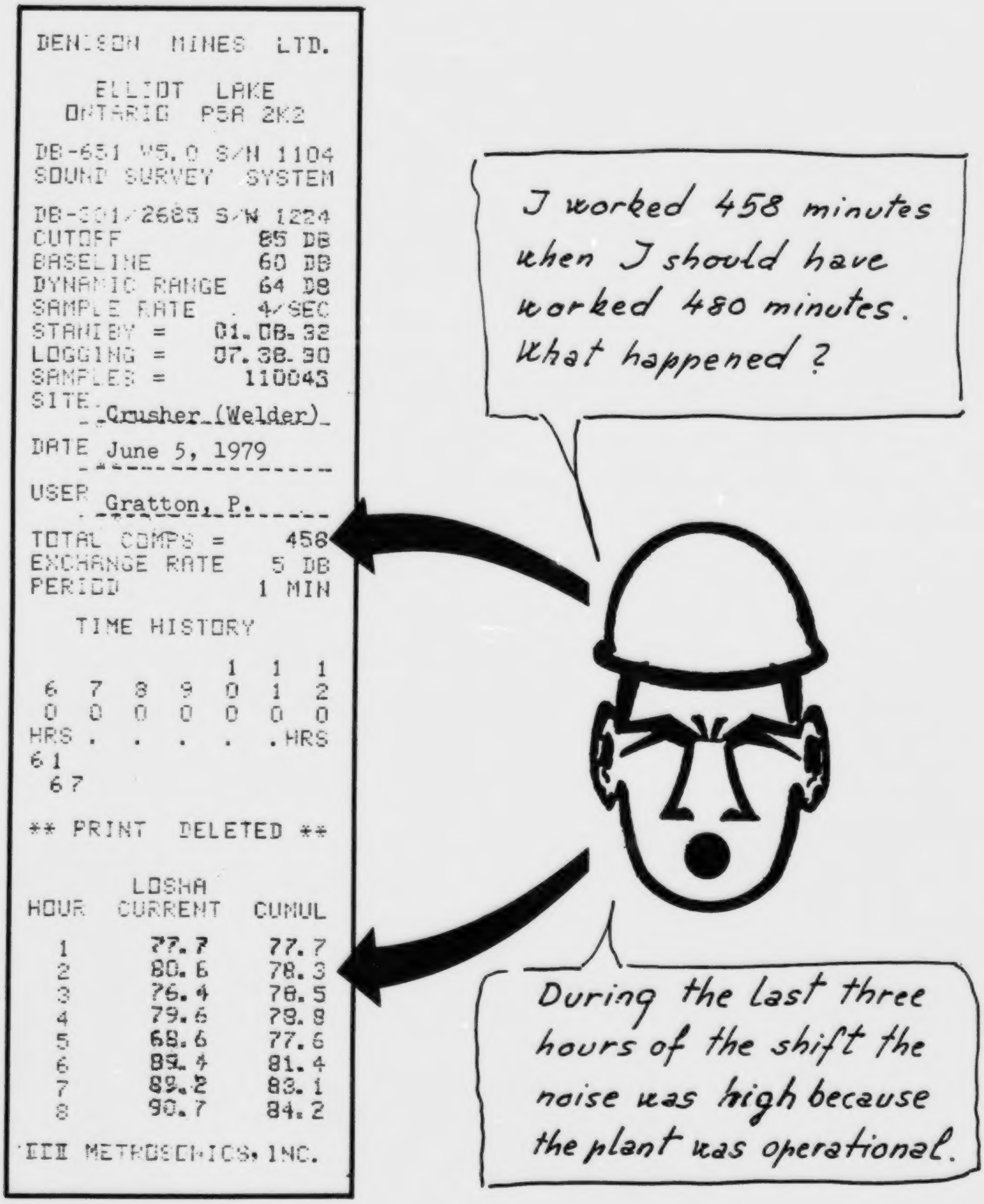
DENISON MINES LIMITED

NOISE SURVEY

DATE: June 5, 1979

INSTR. NO.	NAME	PAYROLL NO. (USER)	OCCUPATION (JOB)	LOCATION (SITE)	REMARKS
1	Storie, J.	0843	001 Mechanic	Crusher	
2	Paquin, C.	0922	001 Mechanic	Crusher	
3	Punkkenen, A.	4423	143 Mechanic	Crusher	
6	Jamieson, W.	0735	001 Mechanic	Crusher	Error 1 Logger not sending
7	Zammit, W.	0195	011 Mechanic	Crusher	
8	Peters, D.	0294	172 Operator	Crusher	
9	Hemmingway, A.	0637	143 Mechanic	Crusher	
10	Leond, E.	0280	001 Mechanic	Crusher	New Battery
11	Young, B.	9585	Mech.\MEF Foreman	Crusher	
13	Gratton, P.	4377	014 Welder	Crusher	
14	Ready, A.	0378	Cone\172 Operator	Crusher	
15	Savard, N.	0132	004 Welder	Crusher	

Partial Information on the Noise Dosimeter Survey:
L_{OSHA} (current and cumulative)



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DENISON  MINES  LTD.

    ELLIOT  LAKE
  ONTARIO  P5A 2K2

DB-651 V5.0 S/N 1104
SOUND SURVEY  SYSTEM

DB-301/2685 S/N 1224
CUTOFF           85 DB
BASELINE         60 DB
DYNAMIC RANGE    64 DB
SAMPLE RATE    . 4/SEC
STANDBY =     01.08.32
LOGGING =     07.38.30
SAMPLES =       110043
SITE
  _Crusher (Welder)_

DATE June 5, 1979
  _________________

USER Gratton, P.
  _________________

TOTAL COMPS =      458
EXCHANGE RATE     5 DB
PERIOD           1 MIN

   TIME HISTORY

                1  1  1
 6  7  8  9  0  1  2
 0  0  0  0  0  0  0
HRS .  .  .  .  . HRS
6 1
 6 7

** PRINT  DELETED **

       LOSHA
HOUR  CURRENT  CUMUL

 1      77.7    77.7
 2      80.6    78.3
 3      76.4    78.5
 4      79.6    78.8
 5      68.6    77.6
 6      89.4    81.4
 7      89.2    83.1
 8      90.7    84.2

III METROSONICS, INC.
```

I worked 458 minutes when I should have worked 480 minutes. What happened?
During the last three hours of the shift the noise was high because the plant was operational.

Appendix 4

Computer Program

For calculating: LOSHA (current and cumulative): percent dose (current and cumulative); arithmetic mean; std. dev.; variance; Amplitude dist. (graphical) and time history (graphical).

```
      PROGRAM  DB651(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C     M A I N     P R O G R A M
C
C     D A T A     D E C L A R A T I O N S
C
      INTEGER  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE
      INTEGER  PERIOD, STNDBY, SAMPS, SCNT, COMPS
      INTEGER  TIME, DIST, XRATE
      INTEGER  RUNDAY, RUNYR, RUNMO
      INTEGER  LOGDAY, LOGYR, LOGMO
      INTEGER  SITE, USER, JOB
      INTEGER  GET, YES
      DIMENSION  TIME(480), DIST(64)
      DIMENSION  SITE(5), USER(4), JOB(3)
      DIMENSION  MO(4,12)
C
      COMMON  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE,
     1        PERIOD, STNDBY, SAMPS, SCNT, COMPS, TIME, DIST,
     2        XRATE, RUNDAY, RUNMO, RUNYR, LOGDAY, LOGMO, LOGYR,
     3        SITE, USER, JOB
C
      DATA  MO(1, 1),MO(2, 1),MO(3, 1),MO(4, 1) /1H ,1HJ,1HA,1HN/
      DATA  MO(1, 2),MO(2, 2),MO(3, 2),MO(4, 2) /1H ,1HF,1HE,1HB/
      DATA  MO(1, 3),MO(2, 3),MO(3, 3),MO(4, 3) /1H ,1HM,1HA,1HR/
      DATA  MO(1, 4),MO(2, 4),MO(3, 4),MO(4, 4) /1H ,1HA,1HP,1HR/
      DATA  MO(1, 5),MO(2, 5),MO(3, 5),MO(4, 5) /1H ,1HM,1HA,1HY/
      DATA  MO(1, 6),MO(2, 6),MO(3, 6),MO(4, 6) /1HJ,1HU,1HN,1HE/
      DATA  MO(1, 7),MO(2, 7),MO(3, 7),MO(4, 7) /1HJ,1HU,1HL,1HY/
      DATA  MO(1, 8),MO(2, 8),MO(3, 8),MO(4, 8) /1H ,1HA,1HU,1HG/
      DATA  MO(1, 9),MO(2, 9),MO(3, 9),MO(4, 9) /1HS,1HE,1HP,1HT/
      DATA  MO(1,10),MO(2,10),MO(3,10),MO(4,10) /1H ,1HO,1HC,1HT/
      DATA  MO(1,11),MO(2,11),MO(3,11),MO(4,11) /1H ,1HN,1HO,1HV/
      DATA  MO(1,12),MO(2,12),MO(3,12),MO(4,12) /1H ,1HD,1HE,1HC/
      DATA  YES / 1HY /
C
C     F O R M A T S
C
   45 FORMAT(///  17H    DATA LOGGED : ,I2,1X,4A1,I5,
     1         10X, 16HDATA ANALYZED : , I2, 1X, 4A1, I5)
   55 FORMAT (8X, 14HLOGGER : DB-30, I1, 1H/, I2, 17X,
     1         12HSITE CODE : , 5A1)
   65 FORMAT (17H SERIAL NUMBER : , I4, 23X,
     1         11HJOB CODE : , 3A1)
   75 FORMAT (6X, 11HBASELINE : , I2, 3H DB, 21X,
     1         12HUSER CODE : , 4A1 )
   85 FORMAT (17H DYNAMIC RANGE : , I2, 3H DB, 21X,
     1         12HTHRESHOLD : , I3, 3H DB )
   95 FORMAT (17H SAMPLING RATE : , I2, 4H/SEC , 16X,
     1         15HTOTAL SAMPLES =, I8 )
  105 FORMAT (16H TEST DURATION =, I4, 1H:, I2, 1H:, I2,
     1         14X, 14HSTANDBY TIME =, I4, 1H:, I2, 1H:, I2 //)
C
C     G E T     D A T A
C
   10 I = GET(J)
C
C     MOVE TO TOP OF FORM, THEN PRINT HEADER.
C
      WRITE(6,130)
      WRITE (6,45)  LOGDAY, (MO(J,LOGMO),J=1,4), LOGYR,
     1              RUNDAY, (MO(J,RUNMO),J=1,4), RUNYR
      WRITE (6,55)  MODEL, PGM, (SITE(J),J=1,5)
      WRITE (6,65)  SERIAL, (JOB(J),J=1,3)
      WRITE (6,75)  BASE, (USER(J),J=1,4)
      WRITE (6,85)  RANGE, CUTOFF
      WRITE (6,95)  SRATE, SAMPS
      ILSEC = MOD(SAMPS/SRATE,60)
      ILMIN = MOD(SAMPS/(60 * SRATE),60)
      ILHRS = SAMPS/(3600 * SRATE)
      ISSEC = MOD(STNDBY/SRATE,60)
      ISMIN = MOD(STNDBY/(60 * SRATE),60)
      ISHRS = STNDBY / (3600 * SRATE)
      WRITE (6,105)  ILHRS, ILMIN, ILSEC, ISHRS, ISMIN, ISSEC
```

```
C
C     A N Y    D A T A    L O G G E D   ?
C
      IF ( SAMPS .GT. 0 )  GO TO 20
  135 FORMAT (15HONO DATA LOGGED )
      WRITE (6,135)
      GO TO 40
C
C     W H I C H    P R O G R A M    T O    R U N  ?
C
   20 IF  ( I .EQ. 3 )  GO TO 30
      IF  ( I .EQ. 0 )  XRATE = 4
      IF  ( I .EQ. 1 )  XRATE = 3
      IF  ( I .EQ. 2 )  XRATE = 5
      CALL  THPGM
       GO TO 39
   30 CALL  DISTPM
   39 WRITE(6,130)
  130 FORMAT (////)
      GO TO 10
   40 WRITE (6,125)
  125 FORMAT (1HO, ///// 24H E N D    O F    R U N   //// )
      STOP
      END
      INTEGER FUNCTION GET(I)
C
C     THIS PROGRAM PROVIFES A DEMONSTRATION OF THE DB-651 COMPUTER
C     INTERFACE OPTION.  THIS PROGRAM WILL READ AND PROCESS A DB-301
C     LOGGER WITH A /1XCC, /2XCC, /3X, OR /4XCC PROGRAM.
C
C
C     THIS FUNCTION RETURNS THE DB-301 PROGRAM NUMBER (E.G. 1)
C     IN ADDITION, IT ALSO READS IN ALL THE DATA TRANSFERRED BY THE
C     DB-651. IN ADDITION THE ROUTINE GETS THE DATE FROM THE HOST
C     COMPUTER, AND IF DESIRED, MAY BE MODIFYED TO READ IN ANY
C     ADDITIONAL INFORMATION.  IN THIS WAY, THIS IS THE ONLY
C     MACHINE DEPENDANT FUNCTION!
C
C     D A T A    D E C L A R A T I O N S
C
      INTEGER  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE
      INTEGER  PERIOD, STNDBY, SAMPS, SCNT, COMPS
      INTEGER  TIME, DIST, XRATE
C
C     ************  MACHINE DEPENDANT / OPTIONAL
C
      INTEGER  RUNDAY, RUNYR, RUNMO
      INTEGER  LOGDAY, LOGYR, LOGMO
      INTEGER  SITE, USER, JOB
C
C
C     ***********
C
      DIMENSION  TIME(480), DIST(64)
      DIMENSION  SITE(5), USER(4), JOB(3)
C
      COMMON  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE,
     1        PERIOD, STNDBY, SAMPS, SCNT, COMPS, TIME, DIST,
     2        XRATE, RUNDAY, RUNMO, RUNYR, LOGDAY, LOGMO, LOGYR,
     3        SITE, USER, JOB
C
C     D A T A    D E F I N I T I O N S
C
C     THE VARIABLES PRECEEDED BY "*" MUST BE 32 BIT INTEGERS.
C     THE OTHER VARIABLES NEED ONLY BE 16 BIT INTEGERS.
C
C     MODEL - THE 300 SERIES MODEL NUMBER. THIS PROGRAM CAN READ
C             ANY MODEL NUMBER, BUT CAN ONLY PROCESS A MODEL 301.
C
C       PGM - THE PROGRAM NUMBER BEING TRANSFERED. THIS PROGRAM
C             WILL PROCESS PROGRAMS 1, 2, 3, AND 4.
C
C    CUTOFF - IF USED BY THE LOGGER, THIS IS THE VALUE BELOW
C             WHICH, DATA WAS IGNORED BY THE DB-301.
C
C    SERIAL - THE SERIAL NUMBER OF THE LOGGER BEING READ.
C
```

```
C          BASE - THE BASELINE OF THE LOGGER. TYPICALLY 40 OR 60 DB.
C
C         RANGE - THE DYNAMIC RANGE OF THE LOGGER. 64 DB FOR THE 301.
C
C         SRATE - THE SAMPLING RATE OF THE LOGGER. MOST 301'S SAMPLE
C                 4 TIMES PER SECOND ( ANSI SLOW).
C
C        PERIOD - COMPUTATION PERIOD FOR TIME HISTORY
C
C *      STNDBY - THE NUMBER OF SAMPLES NOT LOGGED BECAUSE THE LOGGER
C                 WAS IN STANDBY MODE. THIS COUNT DOES NOT START UNTIL
C                 AT LEAST 1 SAMPLE HAS BEEN LOADED BY THE LOGGER.
C
C *       SAMPS - THE NUMBER OF SAMPLES LOGGED.
C
C          SCNT - THE NUMBER OF TIMES THAT THE LOGGER WAS SWITCHED
C                 FROM RUN MODE TO STANDBY MODE. ONLY USED WITH A
C                 /3X PROGRAM.
C
C         COMPS - THE NUMBER OF COMPUTATIONS PERFORMED BY A TIME
C                 HISTORY ( /1X, /2X, OR /4X) PROGRAM.
C
C          TIME - AN ARRAY FOR THE 480 TIME HISTORY COMPUTATIONS.
C
C *        DIST - AN ARRAY FOR THE 64 DISTRIBUTION BINS.
C
C        RUNAAA - THE DAY, MONTH AND YEAR THAT THIS PROGRAM IS RUNNING.
C
C         ************ MACHINE DEPENDANT / OPTIONAL
C
C        LOGAAA - THE DAY, MONTH AND YEAR THAT THE DATA WAS LOGGED. THIS
C                 INFORMATION IS OPERATOR SUPPLIED. THAT IS, THIS DATA
C                 IS MANUALLY KEYED IN.
C
C          SITE - A 5 CHARACTER SITE CODE. OPERATOR SUPPLIED.
C
C          USER - A 4 CHARACTER USER CODE. OPERATOR SUPPLIED. THIS IS
C                 INTENDED TO BE THE CODE OF THE PERSON WHO WAS
C                 EXPOSED TO THE SOUND (NOISE) RECORDED BY THE LOGGER.
C
C           JOB - A 3 CHARACTER OCCUPATION CODE. THAT IS, FOR EXAMPLE,
C                 THE WEARERS JOB TITLE OR JOB FUNCTION WHILE WEARING
C                 THIS LOGGER. OPERATOR SUPPLIED.
C
C         ************
C
C         F O R M A T S
C
   15 FORMAT (I3, 2X, I2, 2X, I2, 2X, I4, 2X, I3, 2X, I3,
     1         2X, I3, 2X, I3, 2X, I3)
   25 FORMAT (I8, 2X, I8, 2X, I3)
   35 FORMAT (8I8)
   45 FORMAT (16I4)
C
C         ************ MACHINE DEPENDANT / OPTIONAL
C
   55 FORMAT (    //29H ENTER LOG DATE (DD/MM/YR) :    )
   65 FORMAT (I2, 1X, I2, 1X, I2)
   75 FORMAT (29H ENTER SITE CODE (5 CHARS) :    )
   85 FORMAT (5A1)
   95 FORMAT (29H ENTER USER CODE (4 CHARS) :    )
  105 FORMAT (4A1)
  115 FORMAT (29H  ENTER JOB CODE (3 CHARS) :    )
  125 FORMAT (3A1)
  135 FORMAT (33H PLACE TAPE IN READER THEN TYPE A ,
     1         23H 'SPACE' AND A 'RETURN'  )
  145 FORMAT (A1)
  155 FORMAT (3H%TO)
  165 FORMAT (1H0, I4, 30H IS NOT A VALID LOGGER PROGRAM  ,
     1         29H FOR THIS PROGRAM TO PROCESS.
     2         /// 28HP R O G R A M    H A L T S   )
  176 FORMAT (////)
C
C         NOW WE START EXECUTING THE ROUTINE. THE FIRST FUNCTION
C         IS TO GET THE CURRENT DAY, MONTH AND YEAR AND CONVERT IT IF
C         REQUIRED TO THE DESIRED INTERNAL FORMAT.
```

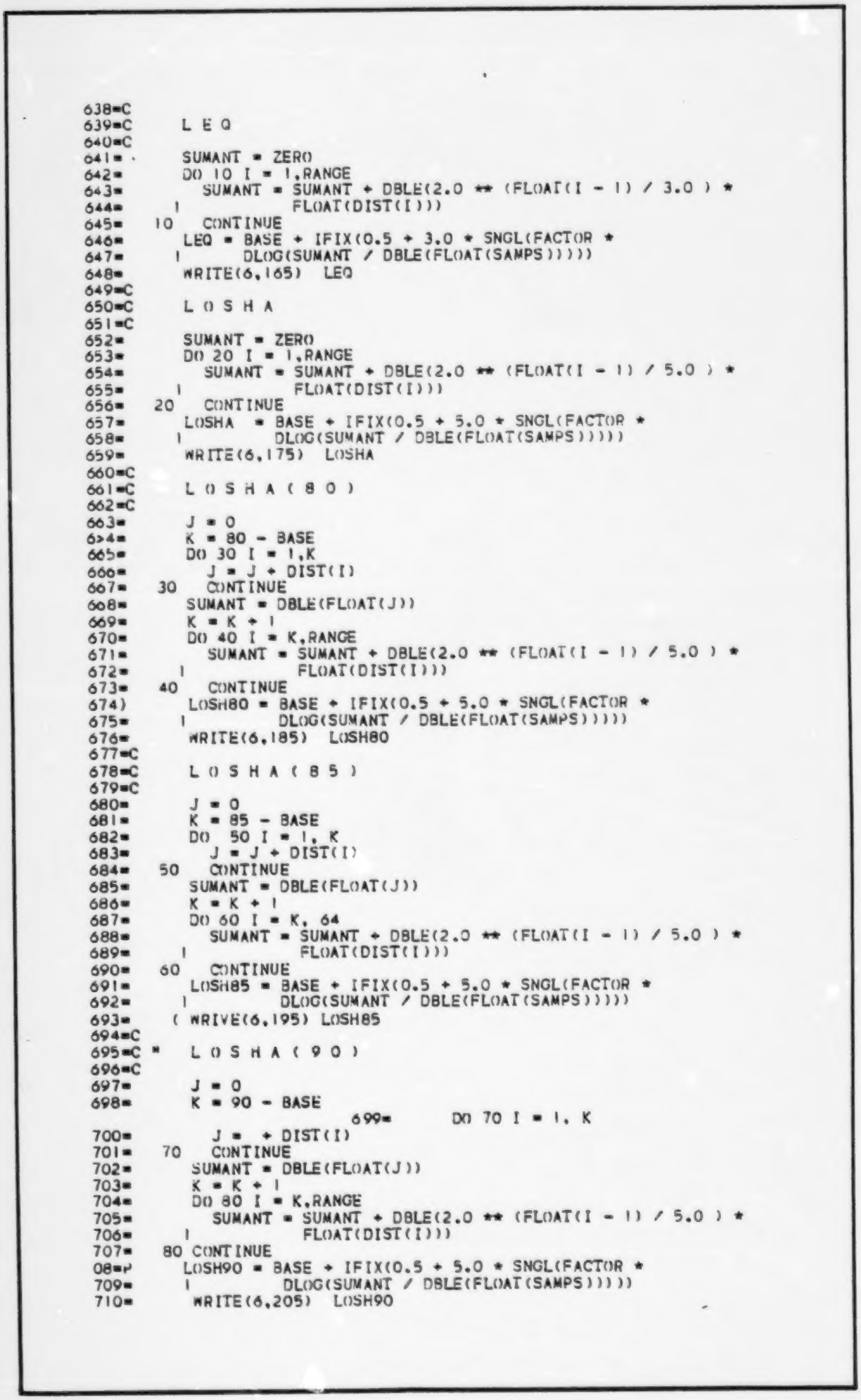
```
C
C     ************ CDC CYBER VERSION ( NOS/BE)
C
  175 FORMAT (1X, I2, 1X, I2, 1X, I2)
      CALL  DATE(TEMP)
C
C     THE CYBER RETURNS A REAL NUMBER WITH 10 CHARACTERS IN "DISPLAY"
C     CODE. THE FORMAT IS " DD/MM/YR ".  THIS IS NOW CONVERTED TO
C     INTEGERS.
C
      DECODE(10,175,TEMP)  RUNDAY, RUNMO, RUNYR
C
C     END OF CDC VERSION
C
      RUNYR = RUNYR + 1900
      GO TO 901
C     NOW WE GET SOME OPTIONAL INFORMATION. IN THIS CASE, WE ASK THE
C     OPERATOR TO TELL US WHEN THE DATA WAS LOGGED, WHO WAS WEARING
C     THE LOGGER, WHERE THE LOGGER WAS BEING WORN, AND WHAT JOB WAS
C     THE WEARER DOING.
  902 CONTINUE
C     L O G    D A T E
C
      WRITE (6,55)
      READ (5,65)  LOGDAY, LOGMO, LOGYR
      LOGYR = LOGYR + 1900
C
C     S I T E    C O D E
C
      WRITE (6,75)
      READ (5,85)  (SITE(I),I=1,5)
C
C     U S E R    I D    C O D E
C
      WRITE (6,95)
      READ (5,105)  (USER(I),I=1,4)
C
C     J O B    C O D E
C
      WRITE (6,115)
      READ (5,125)  (JOB(I),I=1,3)
      GO TO 909
C     THE OPERATOR NOW HAS TO READY THE DATA INPUT DEVICE. WHILE THIS
C     WILL TYPICALLY BE THE DB-651 ITSELF, SOME USERS MAY HAVE STORED
C     THE LOGGER DATA ON AN EXTERNAL MEDIUM (E.G. PAPER TAPE, DIGITAL
C     CASSETTE OR FLOPPY DISC). THE PROGRAM REQUESTS THE USER TO
C     PREPARE FOR TRANSFER OF THE DATA.  THIS PROCEDURE CAN BE VARIED
C     AS REQUIRED FOR EACH INSTALLATION.
C
C     IF THE DB-651 IS CONNECTED TO THE HOST COMPUTER DIRECTLY,
C     PROBABLY ALL THAT IS REQUIRED IS FOR THE OPERATOR TO PLUG
C     THE LOGGER INTO THE DB-651, AND THEN PRESS THE "DATA
C     TRANSFER" PUSHBUTTON ON THEB-651.
C
C     IN THIS EXAMPLE, THE DATA HAS BEEN STORED ON AN EXTERNAL
C     DEVICE WHICH IS 'STARTABLE' BY THE CYBER. THE OPERATOR NEED
C     ONLY POSITION THE TAPE TO THE BEGINNING OF THE FILE TO BE
C     TRANSFERRED.  WHEN THIS IS DONE, THE OPERATOR NEEDS TO TYPE
C     THE 'SPACE' CHARACTER AND THE 'RETURN' KEY TO SIGNAL TO THE
C     PROGRAM TO CONTINUE.
C
C     THE USER SHOULD MODIFY THIS PROCEDURE TO SUIT INDIVIDUAL
C     REQUIREMENTS!
  901 WRITE (6,176)
      WRITE (6,135)
      READ (5,145) I
      WRITE (6,176)
C     S T A R T    R E A D E R
C
      WRITE (6,155)
C
C     G E T    F I R S T    R E C O R D
C
      READ (5,15)  MODEL, PGM, CUTOFF, SERIAL, BASE,
     1             RANGE, SRATE, PERIOD
```

```
C
C     NOW WE DETERMINE WHETHER THIS IS A TIME HISTORY OR DISTRIBUTION
C     PROGRAM.  IF IT IS A TIME HISTORY PROGRAM, WE WILL READ IN 480
C     TIME HISTORY COMPUTATIONS. IF IT IS A DISTRIBUTION PROGRAM, WE
C     WILL READ IN THE 64 DISTRIBUTION BINS.
C
C     W H A T    K I N D    O F    P R O G R A M
C
      GET = PGM / 10
C
C     V A L I D    P R O G R A M    ?
C
      IF  ( GET .EQ. 3 )  GO TO 100
      IF  ( GET )  20, 30, 10
   10 IF  ( GET .EQ. 1 .OR. GET .EQ. 2 )  GO TO 30
   20 WRITE (6,165)  PGM
      STOP
C
C     PROGRAMS 1, 2, AND 4 ARE TIME HISTORY
C
C     G E T    S E C O N D    R E C O R D
C
   30 READ (5,25)  STNDBY, SAMPS, COMPS
C
C     G E T    4 8 0    C O M P U T A T I O N S
C
      DO 40 I = 1,480,16
        J = I + 15
        READ (5,45) (TIME(K).K=I,J)
   40   CONTINUE
C
C     NOW WE HAVE ALL THE INFORMATION NEEDED, AND WE RETURN.
C
      GO TO 902
C
C     PROGRAM 3 IS THE DISTRIBUTION PROGRAM.
C
C     G E T    S E C O N D    R E C O R D
C
  100 READ (5,25)  STNDBY, SAMPS, SCNT
C
C     G E T    6 4    B I N S
C
      DO 1010 I = 1,64,8
        J = I + 7
        READ (5,35)  (DIST(K),K=I.J)
 1010   CONTINUE
      GO TO 902
C     AND AGAIN, IT IS TIME TO RETURN
C
  909 RETURN
      END
      SUBROUTINE DPLOT(SAMPLE)
C
C     D A T A    D E C L A R A T I O N S
C
      INTEGER  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE
      INTEGER  PERIOD, STNDBY, SAMPS, SCNT, COMPS
      INTEGER  TIME, DIST, XRATE
      INTEGER  RUNDAY, RUNYR, RUNMO
      INTEGER  LOGDAY, LOGYR, LOGMO
      INTEGER  SITE, USER, JOB
      INTEGER  DOT, STAR, BLANK, START, SAMPLE
      REAL  ANNOT, ANTABL
C
      DIMENSION  TIME(480), DIST(64)
      DIMENSION  SITE(5), USER(4), JOB(3)
      DIMENSION  LINE(64), ANNOT(60), ANTABL(10), START(64)
C
      COMMON  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE,
     1        PERIOD, STNDBY, SAMPS, SCNT, COMPS, TIME, DIST,
     2        XRATE, RUNDAY, RUNMO, RUNYR, LOGDAY, LOGMO, LOGYR,
     3        SITE, USER, JOB
      DATA  ANTABL /100., 80., 60., 50., 40., 30., 25.,
     1               20., 15., 12./
      DATA  DOT /1H./
      DATA  STAR /1H*/
      DATA  BLANK /1H /
```

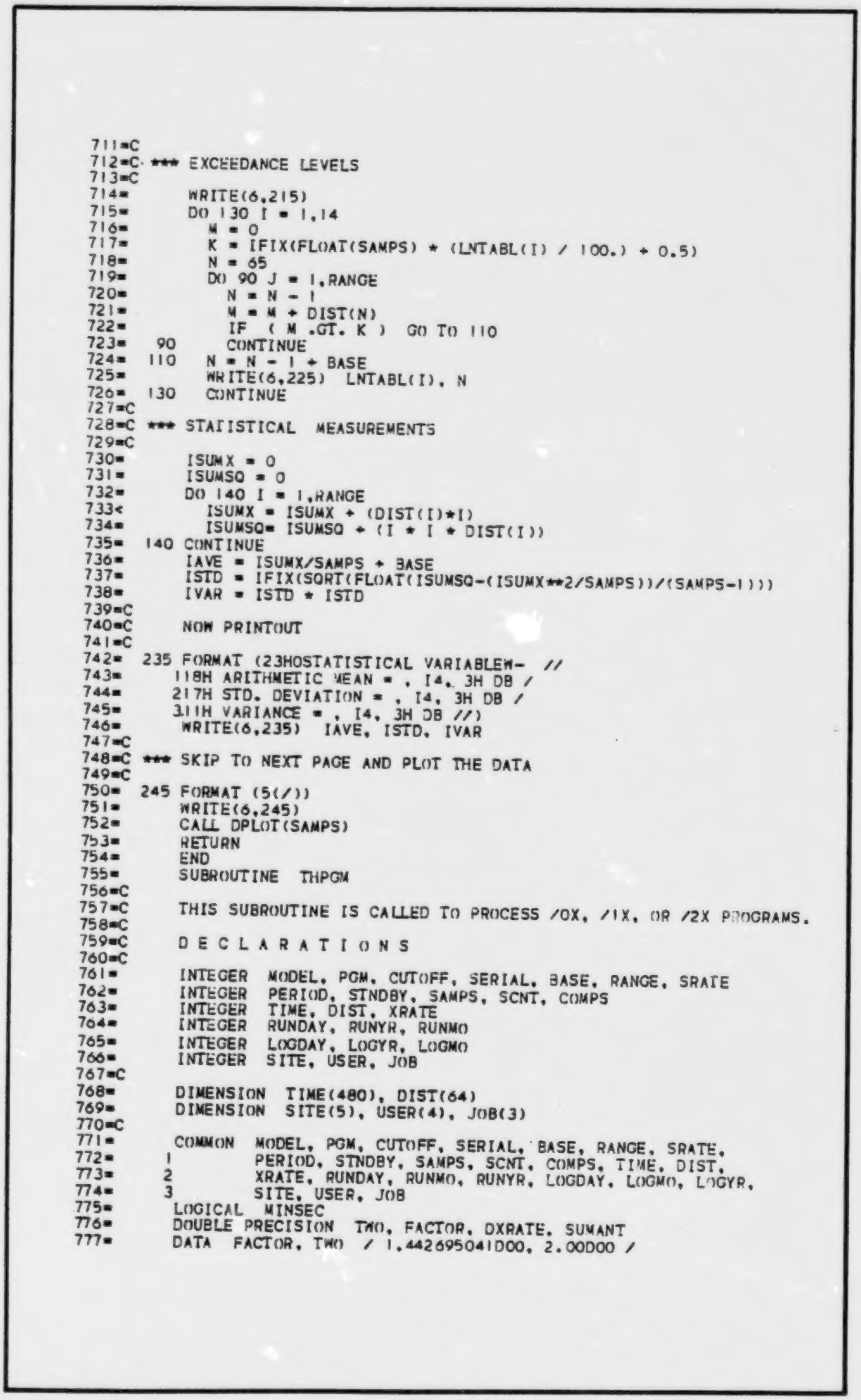
```
C
C *** FORM COMPLETE ANNOTATION FOR PRINTOUT
C
        DO 10 I= 2,60,2
          ANNOT(I) = 0.
   10     CONTINUE
        I = 1
        DO 20 J = 1,10
          ANNOT(I) = ANTABL(J)
          ANNOT(I+20) = ANTABL(J)/10.
          ANNOT(I+40) = ANTABL(J)/100.
          I = I +2
   20     CONTINUE
C
C *** P L O T T E R   F O R M A T S
C
   15 FORMAT(1H0, 25X, 22HAMPLITUDE DISTRIBUTION )
   25 FORMAT(1H , 7X, 64A1)
   35 FORMAT(1H , F6.2, 1H%, 64A1)
   45 FORMAT(1H , 7X, 12(5H+----), 3H+--)
   55 FORMAT(1H , 4X, 13(2X, I3))
   65 FORMAT (1H0, 28X, 15HAMPLITUDE IN DB )
C
C *** START UP
C
        WRITE(6,15)
        DO 30 I=1,64
          LINE(I) = BLANK
   30     CONTINUE
C
C *** CONVERT % TO LOG
C
        ASAMP = FLOAT(SAMPLE/100)
        DO 50 I = 1,64
          PERCNT = FLOAT(DIST(I))/ASAMP
           IF (PERCNT .LT. 0.1 )  GO TO 40
          START(I) = IFIX(20.* (ALOG10(10. * PERCNT))+ 0.5)
          GO TO 50
   40     IF  ( PERCNT .EQ. 0.)  START(I) = -1
          IF  ( PERCNT .NE. 0.)  START(I) = 0
   50     CONTINUE
C
C *** P L O T
C
        K = 61
        DO 80 I =1,60
          K = K - 1
          DO 60 J = 1,64
            IF (START(J) .GE. K )  LINE(J) = STAR
            IF (START(J) .EQ. 0 .AND. I .EQ. 60)  LINE(J)= DOT
   60       CONTINUE
          L = 64
          DO 64 M = 1,63
            IF  ( LINE(L) .NE. BLANK ) GO TO 68
            L = L - 1
   64       CONTINUE
   68     IF  ( MOD(I,2) .EQ. 1 )  GO TO 70
          WRITE(6,25) (LINE(J),J=1,L)
          GO TO 80
   70     WRITE(6,35)  ANNOT(I), (LINE(J),J=1,L)
   80     CONTINUE
C
C *** BOTTOM  ANNOTATION
C
        WRITE(6,45)
        DO 90 I = 1,13
          START(I) = BASE + ((I-1)*5)
   90   CONTINUE
        WRITE(6,55)  (START(I),I=1,13)
        WRITE(6,65)
        RETURN
        END
        SUBROUTINE  THPLOT
C
C       COMPRESSED TIME HISTORY PLOTTING ROUTINE
C
C       D A T A     D E C L A R A T I O N S
C
```

```
      INTEGER  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE
      INTEGER  PERIOD, STNDBY, SAMPS, SCNT, COMPS
      INTEGER  TIME, DIST, XRATE
      INTEGER  RUNDAY, RUNYR, RUNMO
      INTEGER  LOGDAY, LOGYR, LOGMO
      INTEGER  SITE, USER, JOB
      INTEGER  BLANK, STAR, MSINC, MMSS
      LOGICAL  MINSEC
      DOUBLE PRECISION  TWO, FACTOR, DXRATE, SUMANT
      DIMENSION  TIME(480), DIST(64)
      DIMENSION  SITE(5), USER(4), JOB(3)
C
      DIMENSION  LINE(64)
      COMMON  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE,
     1        PERIOD, STNDBY, SAMPS, SCNT, COMPS, TIME, DIST,
     2        XRATE, RUNDAY, RUNMO, RUNYR, LOGDAY, LOGMO, LOGYR,
     3        SITE, USER, JOB
C
C
      DATA  FACTOR, TWO  / 1.442695041D00, 2.00D00 /
      DATA  BLANK, STAR  / 1H , 1H* /
C
C     P R I N T     F O R M A T S
C
   15 FORMAT(1H1,9X,47HC O M P R E S S E D   T I M E   H I S T O R Y)
   25 FORMAT (1H0, 26X, 4HFIVE, I3, 15H MINUTE PERIODS /)
   35 FORMAT (1H0, 26X, 4HFIVE, I3, 15H SECOND PERIODS /)
   45 FORMAT (27X, 13HAVERAGE VALUE, 2X, 7H( LEQ ) //)
   55 FORMAT (27X, 13HAVERAGE VALUE, 2X, 7H( LDOD) //)
   65 FORMAT (27X, 13HAVERAGE VALUE, 2X, 7H(LOSHA) //)
   75 FORMAT (7H HH:MM\, I2, 12(2X,I3))
   85 FORMAT (7H MM:SS\, I2, 12(2X,I3))
   95 FORMAT (7H ------\, 12(5H+----), 4H+--- )
  105 FORMAT (1H , I2, 1H:, I2, 1H\, 64A1 )
  115 FORMAT (1H , 5X, 1H\, 64A1 )
C
C     I N I T I A L I Z A T I O N S
C
      DXRATE = DBLE(FLOAT(XRATE))
      MINSEC = .FALSE.
      IF ( COMPS*60*SRATE*PERIOD .GT. SAMPS )  MINSEC = .TRUE.
      MSINC = 30
      IF ( MOD(PERIOD,2) .EQ. 0 )  MSINC = 0
      IHMINC = PERIOD / 2
      IHHMM = IHMINC
      MMSS = MSINC
C
C     IHMINC IS "HOURS:MINUTES INCREMENT" FOR PLOT ANNOTATION
C     IHHMM  IS NEXT VALUE TO PRINT AS ANNOTAION
C
C     P L O T     H E A D E R     L I N E S
C
      WRITE (6,15)
      IF  ( MINSEC )  WRITE (6,35)  PERIOD
      IF  ( .NOT. MINSEC )  WRITE (6,25)  PERIOD
C
      IF  ( XRATE .EQ. 3 )  WRITE (6,45)
      IF  ( XRATE .EQ. 4 )  WRITE (6,55)
      IF  ( XRATE .EQ. 5 )  WRITE (6,65)
C
C     A M P L I T U D E     H E A D E R     L I N E
C
      DO 10 I = 1,13
        LINE(I) = BASE + ((I - 1) * 5)
   10   CONTINUE
      IF  ( MINSEC )  WRITE (6,85)  (LINE(I),I=1,13)
      IF  ( .NOT. MINSEC )  WRITE (6,75)  (LINE(I),I=1,13)
      WRITE (6,95)
C
C     A V E R A G E
C
      DO 100 I = 1,COMPS,5
        J = I + 4
        IF  ( J .GT. COMPS )  J = COMPS
        SUMANT = 0.00D00
        DO 20 K = I,J
          SUMANT = SUMANT + TWO ** (DBLE(FLOAT(TIME(K) - BASE))
     1                  / DXRATE )
   20     CONTINUE
        LAVG = IFIX(0.5 + ((FLOAT(XRATE) * SNGL(FACTOR *
     1             DLOG(SUMANT / DBLE(FLOAT(J - I + 1)))))))
```

```
C
C      P L O T
C
          IF  ( LAVG .EQ. 0 )  GO TO 40
          DO 30 K = 1,LAVG
            LINE(K) = BLANK
   30       CONTINUE
   40     LAVG = LAVG + 1
          LINE(LAVG) = STAR
          IF  ( I .EQ. 1 )  GO TO 48
          IF  ( MOD(I-1,30) .EQ. 0 )  GO TO 50
   48     WRITE (6,115)  (LINE(K),K=1,LAVG)
          GO TO 98
   50     WRITE (6,105)  IHHMM, MMSS, (LINE(K),K=1,LAVG)
C
C      I N C R E M E N T    A N N O T A T I O N    V A L U E S
C
   60     IF  ( MSINC )  70, 90, 70
   70     IF  ( MMSS )  80, 84, 80
   80     MMSS = 0
          IHHMM = IHHMM + 1
          GO TO 90
   84     MMSS = 30
   90     IHHMM = IHHMM + IHMINC
   98     CONTINUE
  100     CONTINUE
C
C      B O T T O M    A N N O T A T I O N
C
       WRITE (6,95)
       DO 110 I = 1,13
         LINE(I) = BASE + ((I - 1) * 5)
  110 CONTINUE
       IF  ( MINSEC )  WRITE (6,85)  (LINE(I),I=1,13)
       IF  ( .NOT. MINSEC )  WRITE (6,75) (LINE(I),I=1,13)
C
       RETURN
       END
       SUBROUTINE  DISTPM
C
C      D A T A    D E C L A R A T I O N S
C
       INTEGER  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE
       INTEGER  PERIOD, STNDBY, SAMPS, SCNT, COMPS
       INTEGER  TIME, DIST, XRATE
       INTEGER  RUNDAY, RUNYR, RUNMO
       INTEGER  LOGDAY, LOGYR, LOGMO
       INTEGER  SITE, USER, JOB
       REAL  LNTABL
       DOUBLE PRECISION  FACTOR, DXRATE, SUMANT, ZERO
C
       DIMENSION  TIME(480), DIST(64)
       DIMENSION  SITE(5), USER(4), JOB(3)
       DIMENSION  LNTABL(14)
C
       COMMON  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE,
     1         PERIOD, STNDBY, SAMPS, SCNT, COMPS, TIME, DIST,
     2         XRATE, RUNDAY, RUNMO, RUNYR, LOGDAY, LOGMO, LOGYR,
     3         SITE, USER, JOB
       DATA  LNTABL  /0., 0.1, 1., 2., 10., 20., 30., 33.33,
     1                40., 50., 60., 66.67, 90., 99./
       DATA  FACTOR, ZERO  / 2.442695D00, 0.0D00 /
C
C      F O R M A T S
C
   15 FORMAT (1HO, 10X, 21HDISTRIBUTION ANALYSIS  /
     1          20HOLOGGING INTERRUPTED , I4, 7H TIMES.  /)
  155 FORMAT (1HO, 13HCOMPUTATIONS- )
  165 FORMAT (1HO, 9HL E Q  = ,I3, 3H DB)
  175 FORMAT (1H , 9HLOSHA  = , I3, 3H DB)
  185 FORMAT (1H , 12HLOSHA(80) = , I3, 3H DB )
  195 FORMAT (1H , 12HLOSHA(85) = , I3, 3H DB )
  205 FORMAT (1H , 12HLOSHA(90) = , I3, 3H DB )
  215 FORMAT (1HO, 18HEXCEEDANCE LEVELS-  /)
  225 FORMAT (1H , 2HL(, F5.2, 4H) = , I3, 3H DB)
      WRITE (6,15)  SCNT
      WRITE (6,155)
```

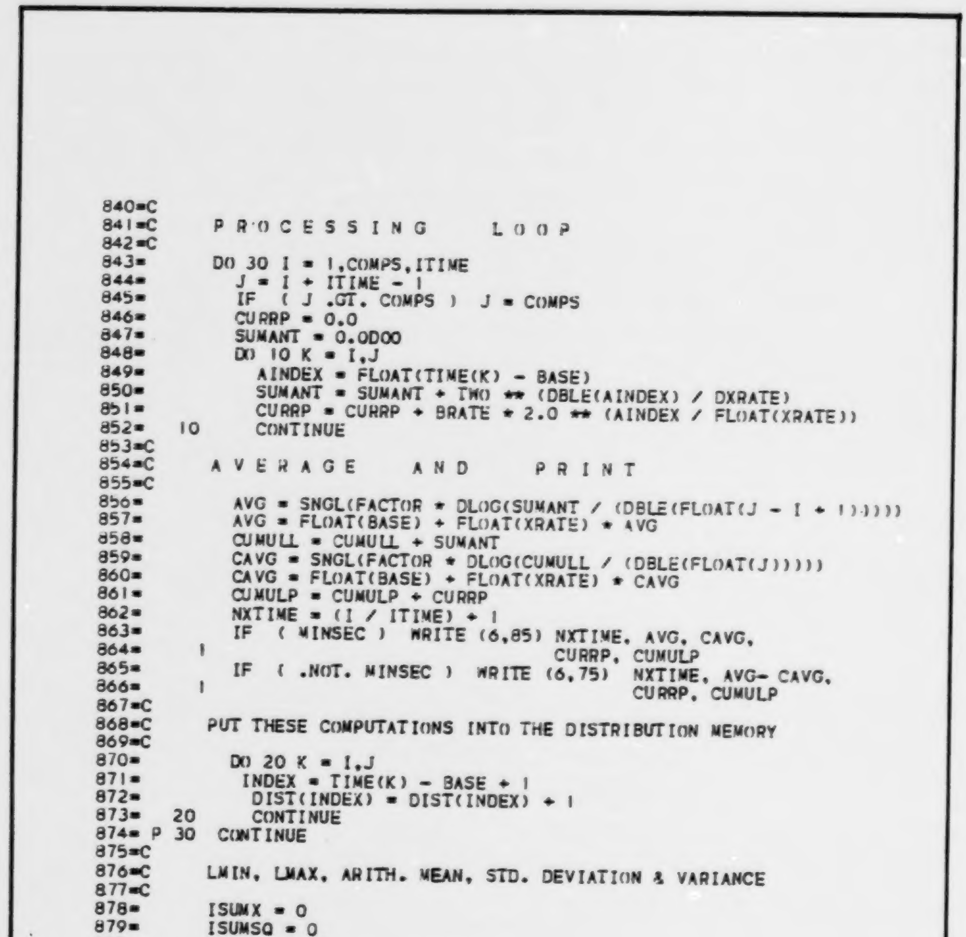


```
C
C     L E Q
C
      SUMANT = ZERO
      DO 10 I = 1,RANGE
        SUMANT = SUMANT + DBLE(2.0 ** (FLOAT(I - 1) / 3.0 ) *
     1               FLOAT(DIST(I)))
   10 CONTINUE
      LEQ = BASE + IFIX(0.5 + 3.0 * SNGL(FACTOR *
     1       DLOG(SUMANT / DBLE(FLOAT(SAMPS)))))
      WRITE(6,165) LEQ
C
C     L O S H A
C
      SUMANT = ZERO
      DO 20 I = 1,RANGE
        SUMANT = SUMANT + DBLE(2.0 ** (FLOAT(I - 1) / 5.0 ) *
     1               FLOAT(DIST(I)))
   20 CONTINUE
      LOSHA  = BASE + IFIX(0.5 + 5.0 * SNGL(FACTOR *
     1             DLOG(SUMANT / DBLE(FLOAT(SAMPS)))))
      WRITE(6,175) LOSHA
C
C     L O S H A ( 8 0 )
C
      J = 0
      K = 80 - BASE
      DO 30 I = 1,K
        J = J + DIST(I)
   30 CONTINUE
      SUMANT = DBLE(FLOAT(J))
      K = K + 1
      DO 40 I = K,RANGE
        SUMANT = SUMANT + DBLE(2.0 ** (FLOAT(I - 1) / 5.0 ) *
     1               FLOAT(DIST(I)))
   40 CONTINUE
      LOSH80 = BASE + IFIX(0.5 + 5.0 * SNGL(FACTOR *
     1             DLOG(SUMANT / DBLE(FLOAT(SAMPS)))))
      WRITE(6,185) LOSH80
C
C     L O S H A ( 8 5 )
C
      J = 0
      K = 85 - BASE
      DO  50 I = 1, K
        J = J + DIST(I)
   50 CONTINUE
      SUMANT = DBLE(FLOAT(J))
      K = K + 1
      DO 60 I = K, 64
        SUMANT = SUMANT + DBLE(2.0 ** (FLOAT(I - 1) / 5.0 ) *
     1               FLOAT(DIST(I)))
   60 CONTINUE
      LOSH85 = BASE + IFIX(0.5 + 5.0 * SNGL(FACTOR *
     1             DLOG(SUMANT / DBLE(FLOAT(SAMPS)))))
     ( WRIVE(6,195) LOSH85
C
C *   L O S H A ( 9 0 )
C
      J = 0
      K = 90 - BASE
      DO 70 I = 1, K
        J =  + DIST(I)
   70 CONTINUE
      SUMANT = DBLE(FLOAT(J))
      K = K + 1
      DO 80 I = K,RANGE
        SUMANT = SUMANT + DBLE(2.0 ** (FLOAT(I - 1) / 5.0 ) *
     1               FLOAT(DIST(I)))
   80 CONTINUE
      LOSH90 = BASE + IFIX(0.5 + 5.0 * SNGL(FACTOR *
     1             DLOG(SUMANT / DBLE(FLOAT(SAMPS)))))
      WRITE(6,205) LOSH90
```



```
C
C *** EXCEEDANCE LEVELS
C
      WRITE(6,215)
      DO 130 I = 1,14
        M = 0
        K = IFIX(FLOAT(SAMPS) * (LNTABL(I) / 100.) + 0.5)
        N = 65
        DO 90 J = 1,RANGE
          N = N - 1
          M = M + DIST(N)
          IF  ( M .GT. K )  GO TO 110
   90     CONTINUE
  110   N = N - 1 + BASE
        WRITE(6,225)  LNTABL(I), N
  130   CONTINUE
C
C *** STATISTICAL  MEASUREMENTS
C
      ISUMX = 0
      ISUMSQ = 0
      DO 140 I = 1,RANGE
        ISUMX = ISUMX + (DIST(I)*I)
        ISUMSQ= ISUMSQ + (I * I * DIST(I))
  140 CONTINUE
      IAVE = ISUMX/SAMPS + BASE
      ISTD = IFIX(SQRT(FLOAT(ISUMSQ-(ISUMX**2/SAMPS))/(SAMPS-1)))
      IVAR = ISTD * ISTD
C
C     NOW PRINTOUT
C
  235 FORMAT (23HOSTATISTICAL VARIABLEW-  //
     118H ARITHMETIC MEAN = , I4, 3H DB /
     217H STD. DEVIATION = , I4, 3H DB /
     311H VARIANCE = , I4, 3H DB //)
      WRITE(6,235)  IAVE, ISTD, IVAR
C
C *** SKIP TO NEXT PAGE AND PLOT THE DATA
C
  245 FORMAT (5(/))
      WRITE(6,245)
      CALL DPLOT(SAMPS)
      RETURN
      END
      SUBROUTINE  THPGM
C
C     THIS SUBROUTINE IS CALLED TO PROCESS /0X, /1X, OR /2X PROGRAMS.
C
C     D E C L A R A T I O N S
C
      INTEGER  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE
      INTEGER  PERIOD, STNDBY, SAMPS, SCNT, COMPS
      INTEGER  TIME, DIST, XRATE
      INTEGER  RUNDAY, RUNYR, RUNMO
      INTEGER  LOGDAY, LOGYR, LOGMO
      INTEGER  SITE, USER, JOB
C
      DIMENSION  TIME(480), DIST(64)
      DIMENSION  SITE(5), USER(4), JOB(3)
C
      COMMON  MODEL, PGM, CUTOFF, SERIAL, BASE, RANGE, SRATE,
     1        PERIOD, STNDBY, SAMPS, SCNT, COMPS, TIME, DIST,
     2        XRATE, RUNDAY, RUNMO, RUNYR, LOGDAY, LOGMO, LOGYR,
     3        SITE, USER, JOB
      LOGICAL  MINSEC
      DOUBLE PRECISION  TWO, FACTOR, DXRATE, SUMANT
      DATA  FACTOR, TWO  / 1.442695041D00, 2.00D00 /
```

```
C
C
C     F O R M A T S
C
   15 FORMAT (1HO, 10X, 21HTIME HISTORY ANALYSIS  //
     1          1H , 42HNOISE EXPOSURE INDEX (N.E.I.) CALCULATIONS  /
     2          29H ARE BASED ON THE FOLLOWING:  /
     3          27H 100% DOSE = 90 DB / 8 HRS  /
     4          27H EXCHANGE (DOUBLING) RATE =, I2, 3H DB /
     5          27H THRESHOLD (CUTOFF) LEVEL =, I3, 3H DB /
     6          27HO  NUMBER OF COMPUTATIONS = , I4 )
   19 FORMAT (9HOPERIOD = , I3, 8H MINUTES // )
   21 FORMAT (9HOPERIOD = , I3, 8H SECONDS // )
   25 FORMAT (6H TIME ,  9X, 5HLOSHA, 19X, 5H%DOSE )
   35 FORMAT (6H TIME ,  9X, 5HL DOD, 19X, 5H%DOSE )
   45 FORMAT (6H TIME ,  9X, 5HL E Q, 19X, 5H%DOSE )
   55 FORMAT (6H HOUR , 3X, 20HCURRENT  CUMULATIVE ,
     1          3X, 20H CURRENT  CUMULATIVE )
   65 FORMAT (6H  MIN , 3X, 20HCURRENT  CUMULATIVE ,
     1          3X, 20H CURRENT  CUMULATIVE )
   75 FORMAT (I5, 5X, F5.1, 5X, F5.1, 6X, F8.3, 2X, F8.2)
   85 FORMAT (I5, 5X, F5.1, 5X, F5.1, 6X, F8.4, 2X, F8.3)
   95 FORMAT (13HOMIN. COMP. =, I4, 3H DB, 10X,
     1           13H MAX. COMP. =, I4, 3H DB )
  105 FORMAT (19HOARITHMETIC MEAN = , I3, 3H DB )
  115 FORMAT (18H STD. DEVIATION = , I3, 3H DB )
  125 FORMAT (11H VARIANCE = , I3, 3H DB )
  135 FORMAT (1HO, 10(/))
C
C     W H I C H    F O R M A T S    ?
C
      MINSEC = .FALSE.
      IF  ( COMPS*60*SRATE*PERIOD .GT. SAMPS )  MINSEC = .TRUE.
C
C     H E A D E R
C
      WRITE (6,15)  XRATE, CUTOFF, COMPS
      IF  ( MINSEC )  WRITE (6,21)  PERIOD
      IF  ( .NOT. MINSEC )  WRITE (6,19)  PERIOD
      IF  ( XRATE .EQ. 3 )  WRITE (6,45)
      IF  ( XRATE .EQ. 4 )  WRITE (6,35)
      IF  ( XRATE .EQ. 5 )  WRITE (6,25)
      IF  ( MINSEC )  WRITE (6,65)
      IF  ( .NOT. MINSEC )  WRITE (6,55)
C
C     A V E R A G E    3 0 / 6 0    C O M P U T A T I O N S
C
C     CALCULATE % DOSE OF 1 PERIOD AT BASELINE.
C
      BDBLE = 100.0 / 2 ** (FLOAT(90 - BASE) / FLOAT(XRATE))
      IF  ( .NOT. MINSEC )  BRATE = BDBLE * FLOAT(PERIOD) / 480.0
      IF  ( MINSEC )  BRATE = BDBLE * FLOAT(PERIOD) / 28800.0
C
C     INITIALIZE CUMULATIVE DOSE , LAVG, AND DIST.
C
      CUMULL = 0.0D00
      CUMULP = 0.0
      ITIME = MOD(PERIOD,2) * 30 + 30
      DXRATE = DBLE(FLOAT(XRATE))
      DO 6  I = 1,RANGE
        DIST(I) = 0
    6   CONTINUE
```

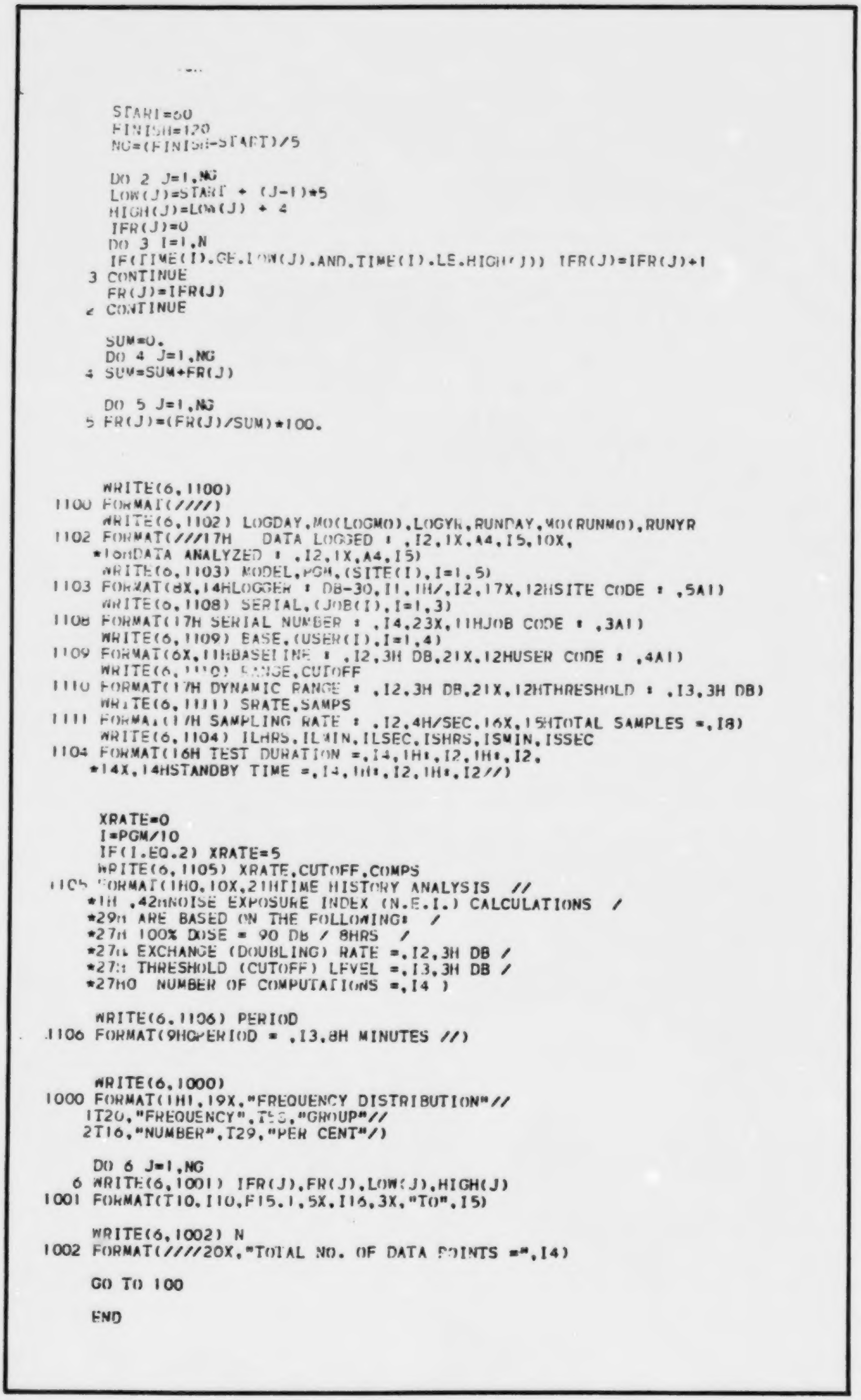


```
C
C     P R O C E S S I N G     L O O P
C
      DO 30 I = 1,COMPS,ITIME
        J = I + ITIME - 1
        IF  ( J .GT. COMPS )  J = COMPS
        CURRP = 0.0
        SUMANT = 0.0D00
        DO 10 K = I,J
          AINDEX = FLOAT(TIME(K) - BASE)
          SUMANT = SUMANT + TWO ** (DBLE(AINDEX) / DXRATE)
          CURRP = CURRP + BRATE * 2.0 ** (AINDEX / FLOAT(XRATE))
   10     CONTINUE
C
C     A V E R A G E     A N D     P R I N T
C
        AVG = SNGL(FACTOR * DLOG(SUMANT / (DBLE(FLOAT(J - I + 1)))))
        AVG = FLOAT(BASE) + FLOAT(XRATE) * AVG
        CUMULL = CUMULL + SUMANT
        CAVG = SNGL(FACTOR * DLOG(CUMULL / (DBLE(FLOAT(J)))))
        CAVG = FLOAT(BASE) + FLOAT(XRATE) * CAVG
        CUMULP = CUMULP + CURRP
        NXTIME = (I / ITIME) + 1
        IF  ( MINSEC )  WRITE (6,85) NXTIME, AVG, CAVG,
     1                               CURRP, CUMULP
        IF  ( .NOT. MINSEC )  WRITE (6,75)  NXTIME, AVG- CAVG,
     1                                      CURRP, CUMULP
C
C     PUT THESE COMPUTATIONS INTO THE DISTRIBUTION MEMORY
C
        DO 20 K = I,J
         INDEX = TIME(K) - BASE + 1
          DIST(INDEX) = DIST(INDEX) + 1
   20     CONTINUE
P  30  CONTINUE
C
C     LMIN, LMAX, ARITH. MEAN, STD. DEVIATION & VARIANCE
C
      ISUMX = 0
      ISUMSQ = 0
      LMAX = BASE
      LMIN = BASE + RANGE - 1
      DO 40 I = 1,COMPS
        IF  ( TIME(I) .GT. LMAX )  LMAX = TIME(I)
        IF  ( TIME(I) .LT. LMIN )  LMIN(= TIME(I)
        ISUMX = ISUMX + TIME(I)
        ISUMSQ = ISUMSQ + (TIME(I) * TIME(I))
   40   CONTINUE
      WRITE (6,95)  LMIN, LMAX
      IAVE = ISUMX / COMPS
      ISTD = IFIX(0.5 + SQRT(FLOAT((ISUMSQ -
PP   1        (ISUMX * ISUMX / COMPS)) o (COMPS - 1))))
      IVAR = ISTD * ISTD
      WRITE (6,105)  IAVE
      WRITE (6,115)  ISTD
      WRITE (6,125)  IVAR
      WRITE (6,135)
      CALL  DPLOT(COMPS)
      CALL  THPLOT
      RETURN
      END
••
```

Computer Program

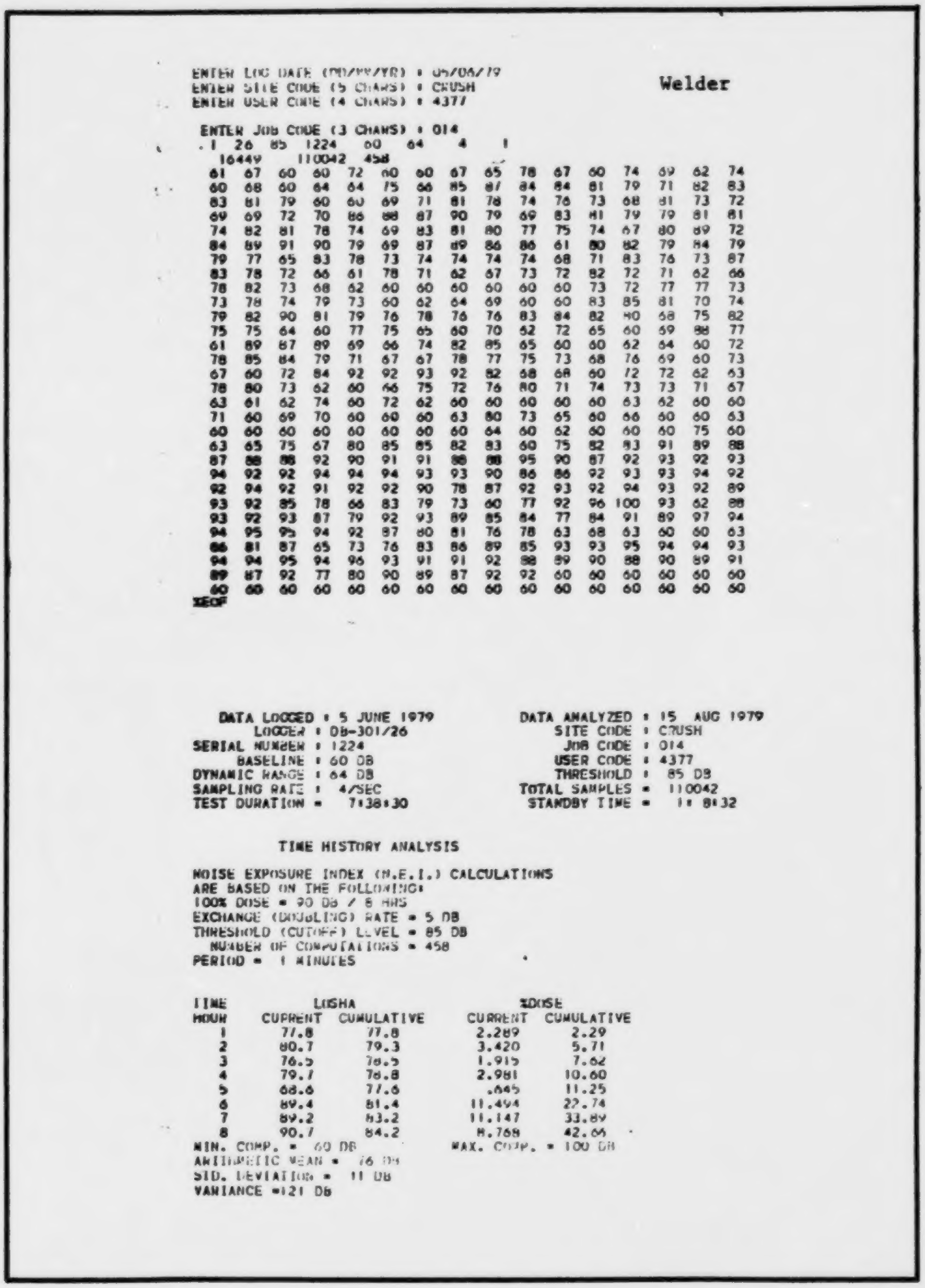
For calculating Frequency Distribution (Numerical).

```
      PROGRAM SAVICH(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      INTEGER MODEL,PGM,CUTOFF,SERIAL,BASE,RANGE,SRATE,PERIOD,DATE1
      INTEGER STNDBY,SAMPS,COMPS,START,FINISH,XRATE
      INTEGER RUNDAY,RUNYR,RUNMO
      INTEGER TIME(480),LOW(20),HIGH(20),IFR(20),SITE(5),USER(4),JOB(3)
      REAL FR(20)
      INTEGER MO(12)
      DATA MO/" JAN"," FEB"," MAR"," APR"," MAY","JUNE","JULY"," AUG",
     *"SEPT"," OCT"," NOV"," DEC"/

      CALL DATE(DATE1)
      DECODE(10,175,DATE1) RUNDAY,RUNMO,RUNYR
  175 FORMAT(1X,I2,1X,I2,1X,I2)
      RUNYR=RUNYR+1900

  100 CONTINUE

      WRITE(6,177)
  177 FORMAT(1H1)
      WRITE(6,135)
  135 FORMAT(33H PLACE TAPE IN READER THEN TYPE A,
     *23H "SPACE" AND A "RETURN")
      READ(5,145) I
  145 FORMAT(A1)
      WRITE(6,176)
  176 FORMAT(////)
      WRITE(6,155)
  155 FORMAT(3HXTO)


      READ(5,15) MODEL,PGM,CUTOFF,SERIAL,BASE,RANGE,SRATE,PERIOD
   15 FORMAT(I3,2X,I2,2X,I2,2X,I4,2X,I3,2X,I3,2X,I3,2X,I3)

      READ(5,25) STNDBY,SAMPS,COMPS
   25 FORMAT(I8,2X,I8,2X,I3)

      ILSEC=MOD(SAMPS/SRATE,60)
      ILMIN=MOD(SAMPS/(60*SRATE),60)
      ILHRS=SAMPS/(3600*SRATE)
      ISSEC=MOD(STNDBY/SRATE,60)
      ISMIN=MOD(STNDBY/(60*SRATE),60)
      ISHRS=STNDBY/(3600*SRATE)

      N=480
      DO 40 I=1,N,16
      J=I+15
      READ(5,45) (TIME(K),K=I,J)
   45 FORMAT(16I4)
   40 CONTINUE


      WRITE(6,55)
   55 FORMAT(//29H ENTER LOG DATE (DD/MM/YR) : )
      READ(5,65) LOGDAY,LOGMO,LOGYR
   65 FORMAT(I2,1X,I2,1X,I2)
      LOGYR=LOGYR+1900
      WRITE(6,75)
   75 FORMAT(" ENTER SITE CODE (5 CHARS) : ")
      READ(5,85) (SITE(I),I=1,5)
   85 FORMAT(5A1)
      WRITE(6,95)
   95 FORMAT(" ENTER USER CODE (4 CHARS) : ")
      READ(5,105) (USER(I),I=1,4)
  105 FORMAT(4A1)
      WRITE(6,115)
  115 FORMAT("  ENTER JOB CODE (3 CHARS) : ")
      READ(5,125) (JOB(I),I=1,3)
  125 FORMAT(3A1)
```



```
      START=60
      FINISH=120
      NG=(FINISH-START)/5

      DO 2 J=1,NG
      LOW(J)=START + (J-1)*5
      HIGH(J)=LOW(J) + 4
      IFR(J)=0
      DO 3 I=1,N
      IF(TIME(I).GE.LOW(J).AND.TIME(I).LE.HIGH(J)) IFR(J)=IFR(J)+1
    3 CONTINUE
      FR(J)=IFR(J)
    2 CONTINUE

      SUM=0.
      DO 4 J=1,NG
    4 SUM=SUM+FR(J)

      DO 5 J=1,NG
    5 FR(J)=(FR(J)/SUM)*100.



      WRITE(6,1100)
 1100 FORMAT(////)
      WRITE(6,1102) LOGDAY,MO(LOGMO),LOGYR,RUNDAY,MO(RUNMO),RUNYR
 1102 FORMAT(///17H    DATA LOGGED : ,I2,1X,A4,I5,10X,
     *16HDATA ANALYZED : ,I2,1X,A4,I5)
      WRITE(6,1103) MODEL,PGM,(SITE(I),I=1,5)
 1103 FORMAT(8X,14HLOGGER : DB-30,I1,1H/,I2,17X,12HSITE CODE : ,5A1)
      WRITE(6,1108) SERIAL,(JOB(I),I=1,3)
 1108 FORMAT(17H SERIAL NUMBER : ,I4,23X,11HJOB CODE : ,3A1)
      WRITE(6,1109) BASE,(USER(I),I=1,4)
 1109 FORMAT(6X,11HBASELINE : ,I2,3H DB,21X,12HUSER CODE : ,4A1)
      WRITE(6,1110) RANGE,CUTOFF
 1110 FORMAT(17H DYNAMIC RANGE : ,I2,3H DB,21X,12HTHRESHOLD : ,I3,3H DB)
      WRITE(6,1111) SRATE,SAMPS
 1111 FORMAT(17H SAMPLING RATE : ,I2,4H/SEC,16X,15HTOTAL SAMPLES =,I8)
      WRITE(6,1104) ILHRS,ILMIN,ILSEC,ISHRS,ISMIN,ISSEC
 1104 FORMAT(16H TEST DURATION =,I4,1H:,I2,1H:,I2,
     *14X,14HSTANDBY TIME =,I4,1H:,I2,1H:,I2//)


      XRATE=0
      I=PGM/10
      IF(I.EQ.2) XRATE=5
      WRITE(6,1105) XRATE,CUTOFF,COMPS
 1105 FORMAT(1H0,10X,21HTIME HISTORY ANALYSIS  //
     *1H ,42HNOISE EXPOSURE INDEX (N.E.I.) CALCULATIONS  /
     *29H ARE BASED ON THE FOLLOWING:  /
     *27H 100% DOSE = 90 DB / 8HRS  /
     *27H EXCHANGE (DOUBLING) RATE =,I2,3H DB /
     *27H THRESHOLD (CUTOFF) LEVEL =,I3,3H DB /
     *27H0  NUMBER OF COMPUTATIONS =,I4 )

      WRITE(6,1106) PERIOD
 1106 FORMAT(9H0PERIOD = ,I3,8H MINUTES //)


      WRITE(6,1000)
 1000 FORMAT(1H1,19X,"FREQUENCY DISTRIBUTION"//
     1T20,"FREQUENCY",T35,"GROUP"//
     2T16,"NUMBER",T29,"PER CENT"/)

      DO 6 J=1,NG
    6 WRITE(6,1001) IFR(J),FR(J),LOW(J),HIGH(J)
 1001 FORMAT(T10,I10,F15.1,5X,I16,3X,"TO",I5)

      WRITE(6,1002) N
 1002 FORMAT(////20X,"TOTAL NO. OF DATA POINTS =",I4)

      GO TO 100

      END
```

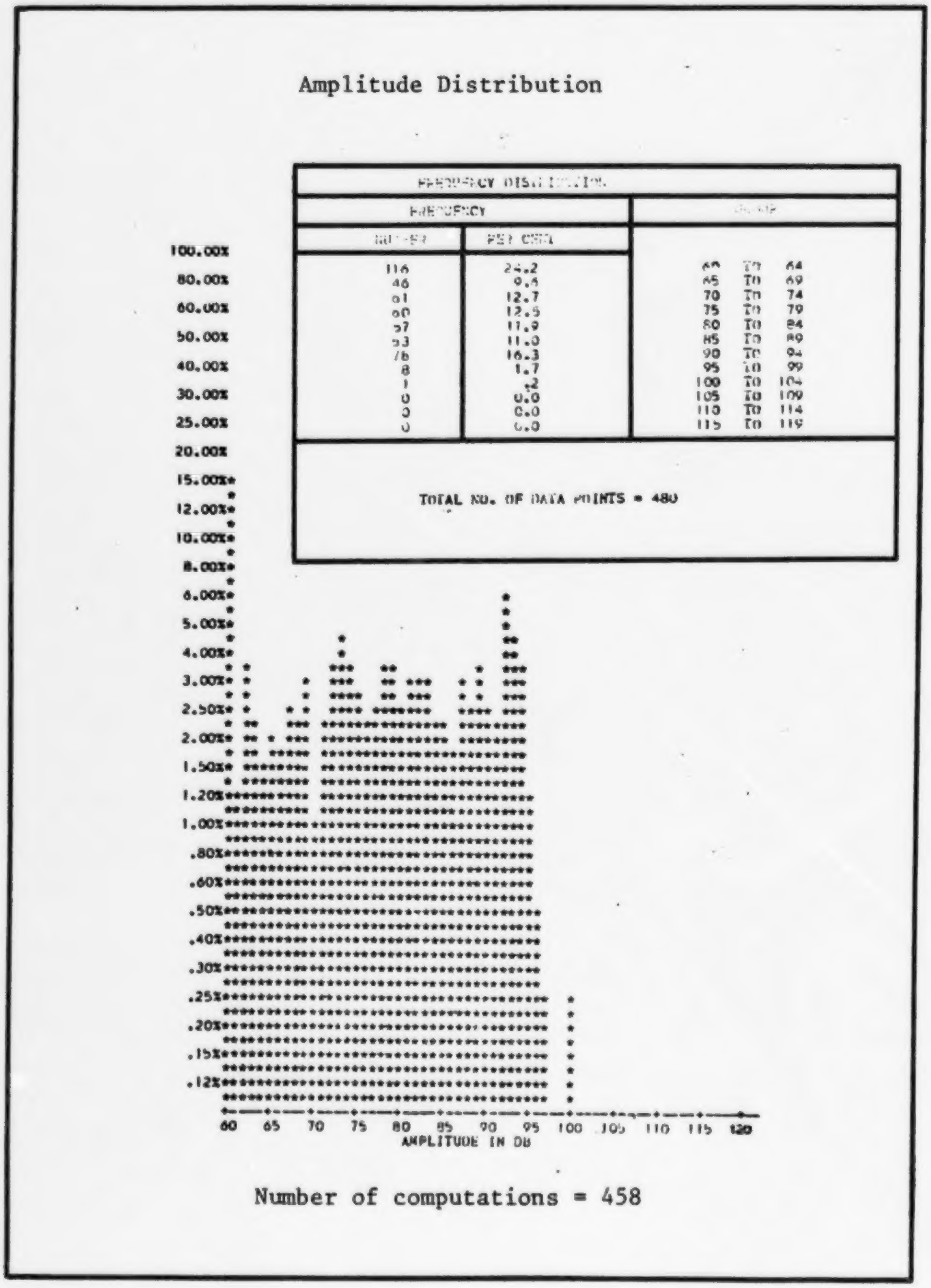
Full Information of the Noise Dosimeter Survey
- Basic Data -



Welder

```
ENTER LOG DATE (MM/DD/YR) : 05/06/79
ENTER SITE CODE (5 CHARS) : CRUSH
ENTER USER CODE (4 CHARS) : 4377

 ENTER JOB CODE (3 CHARS) : 014
 . 1  26  85  1224   60   64    4    1
   16449     110042  458
  61  67  60  60  72  60  60  67  65  78  67  60  74  69  62  74
  60  68  60  64  64  75  66  85  87  84  84  81  79  71  82  83
  83  81  79  60  60  69  71  81  78  74  76  73  68  81  73  72
  69  69  72  70  86  88  87  90  79  69  83  81  79  79  81  81
  74  82  81  78  74  69  83  81  80  77  75  74  67  80  89  72
  84  89  91  90  79  69  87  89  86  86  61  80  82  79  84  79
  79  77  65  83  78  73  74  74  74  74  68  71  83  76  73  87
  83  78  72  66  61  78  71  62  67  73  72  82  72  71  62  66
  78  82  73  68  62  60  60  60  60  60  60  73  72  77  77  73
  73  78  74  79  73  60  62  64  69  60  60  83  85  81  70  74
  79  82  90  81  79  76  78  76  76  83  84  82  80  68  75  82
  75  75  64  60  77  75  65  60  70  62  72  65  60  69  88  77
  61  89  87  89  69  66  74  82  85  65  60  60  62  64  60  72
  78  85  84  79  71  67  67  78  77  75  73  68  76  69  60  73
  67  60  72  84  92  92  93  92  82  68  68  60  72  72  62  63
  78  80  73  62  60  66  75  72  76  80  71  74  73  73  71  67
  63  61  62  74  60  72  62  60  60  60  60  60  63  62  60  60
  71  60  69  70  60  60  60  63  80  73  65  60  66  60  60  63
  60  60  60  60  60  60  60  60  64  60  62  60  60  60  75  60
  63  65  75  67  80  85  85  82  83  60  75  82  83  91  89  88
  87  88  88  92  90  91  91  88  88  95  90  87  92  93  92  93
  94  92  92  94  94  94  93  93  90  86  86  92  93  93  94  92
  92  94  92  91  92  92  90  78  87  92  93  92  94  93  92  89
  93  92  85  78  66  83  79  73  60  77  92  96 100  93  62  88
  93  92  93  87  79  92  93  89  85  84  77  84  91  89  97  94
  94  95  95  94  92  87  80  81  76  78  63  68  63  60  60  63
  86  81  87  65  73  76  83  86  89  85  93  93  95  94  94  93
  94  94  95  94  96  93  91  91  92  88  89  90  88  90  89  91
  89  87  92  77  80  90  89  87  92  92  60  60  60  60  60  60
  60  60  60  60  60  60  60  60  60  60  60  60  60  60  60  60
%EOF



     DATA LOGGED : 5 JUNE 1979              DATA ANALYZED : 15  AUG 1979
          LOGGER : DB-301/26                    SITE CODE : CRUSH
   SERIAL NUMBER : 1224                          JOB CODE : 014
        BASELINE : 60 DB                        USER CODE : 4377
   DYNAMIC RANGE : 64 DB                        THRESHOLD :  85 DB
   SAMPLING RATE :  4/SEC                   TOTAL SAMPLES =  110042
   TEST DURATION =   7:38:30                 STANDBY TIME =   1: 8:32

         TIME HISTORY ANALYSIS

   NOISE EXPOSURE INDEX (N.E.I.) CALCULATIONS
   ARE BASED ON THE FOLLOWING:
   100% DOSE = 90 DB / 8 HRS
   EXCHANGE (DOUBLING) RATE = 5 DB
   THRESHOLD (CUTOFF) LEVEL = 85 DB
     NUMBER OF COMPUTATIONS = 458
   PERIOD =  1 MINUTES

   TIME          LOSHA                    %DOSE
   HOUR     CURRENT  CUMULATIVE      CURRENT  CUMULATIVE
      1       77.8       77.8         2.289       2.29
      2       80.7       79.3         3.420       5.71
      3       76.5       78.5         1.915       7.62
      4       79.7       78.8         2.981      10.60
      5       68.6       77.6          .645      11.25
      6       89.4       81.4        11.494      22.74
      7       89.2       83.2        11.147      33.89
      8       90.7       84.2         8.768      42.66
   MIN. COMP. =  60 DB               MAX. COMP. = 100 DB
   ARITHMETIC MEAN =  76 DB
   STD. DEVIATION =  11 DB
   VARIANCE =121 DB
```

- Amplitude Distribution -
(Numerical & Graphical)



Amplitude Distribution

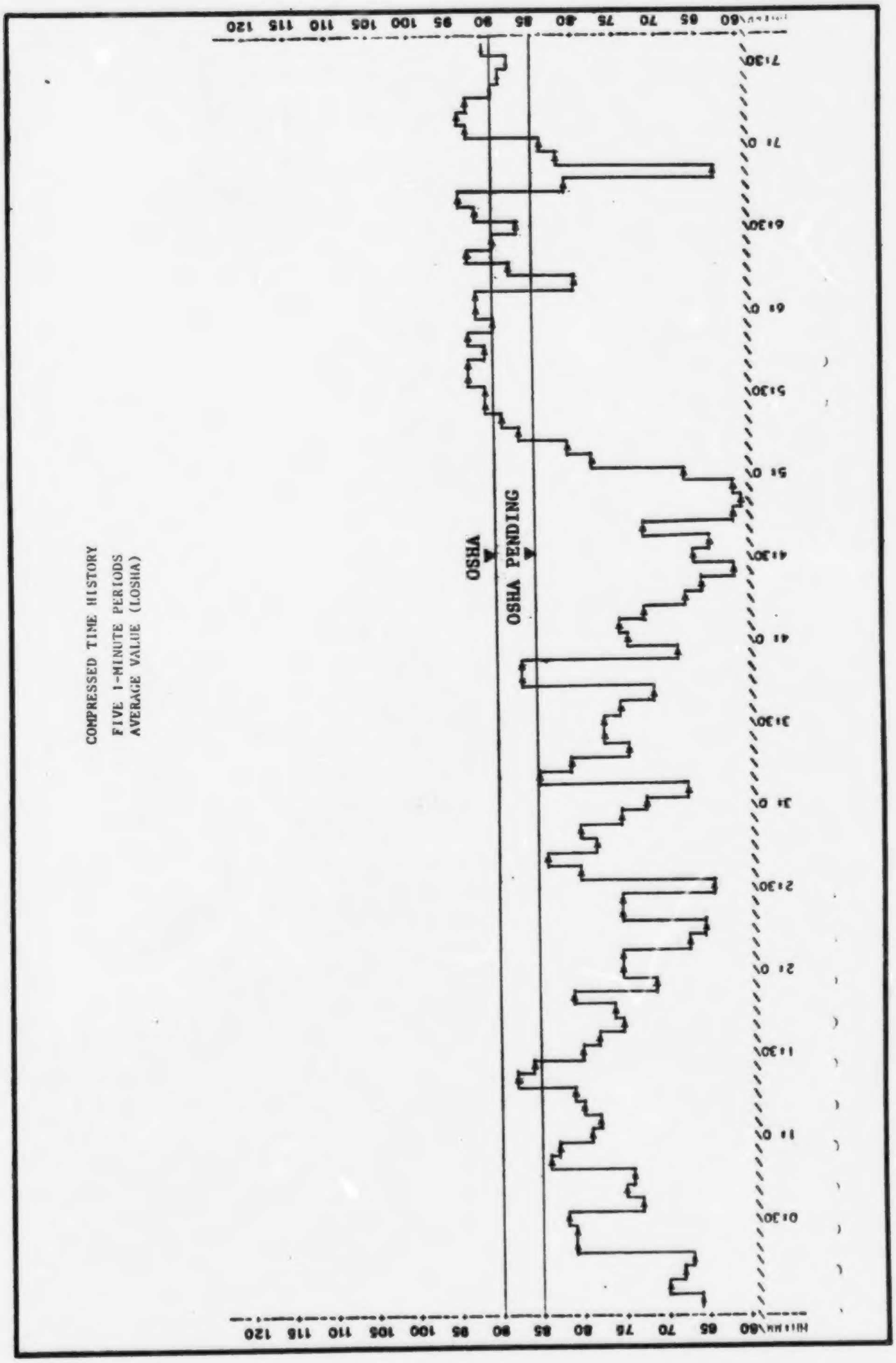
FREQUENCY DISTRIBUTION

FREQUENCY		RANGE
NUMBER	PER CENT	
116	24.2	60 TO 64
46	9.6	65 TO 69
61	12.7	70 TO 74
60	12.5	75 TO 79
57	11.9	80 TO 84
53	11.0	85 TO 89
76	16.3	90 TO 94
8	1.7	95 TO 99
1	.2	100 TO 104
0	0.0	105 TO 109
0	0.0	110 TO 114
0	0.0	115 TO 119

TOTAL NO. OF DATA POINTS = 480

Number of computations = 458

- Time History (Graphical) -



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Noise measurement at Denison Mines Ltd.

in Elliot Lake

1981

NOUVELLE GÉNÉRATION DE DOSIMÈTRES DE BRUIT DANS LES MINES CANADIENNES

par

M.U. Savich*

RÉSUMÉ

Au cours des dix dernières années, de grands progrès ont été réalisés dans le domaine de la lutte contre le bruit dans les mines canadiennes. On a effectué des mesures dans le but de protéger l'ouïe du mineur et la méthode pourra un jour être complètement automatisée et informatisée.

La nouvelle génération de dosimètres de bruit contribue à la résolution des problèmes suivants :

a) sécurité des travailleurs
b) santé des travailleurs
c) conséquences environnementales
d) productivité.

Le système met en évidence le rôle important du programme informatisé fondé sur le calcul total pendant le poste de travail (8 h = 480 min) avec moyennage toutes les minutes de L_{OSHA}. On peut ainsi obtenir des données complètes : variation en fonction du temps (numérique), code du site, code de la

---

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tâche, code de l'utilisateur, nombre de calculs (temps), L_{OSHA} (courant et cumulatif), dose en pourcentage (courante et cumulative), calcul de minimums, calcul de maximums, moyenne arithmétique, écart-type, variance, distribution de l'amplitude (numérique et graphique) et variation en fonction du temps (graphique).

L'une des principales contributions de cette recherche est de montrer comment les dosimètres de bruit de deuxième génération permettent de recueillir des données plus pertinentes. Les mesures seront grandement simplifiées si les nouveaux dosimètres de bruit sont incorporés dans le casque.

NEW GENERATION OF NOISE DOSIMETERS IN CANADIAN MINES

by

M.U. Savich*

ABSTRACT

In the last ten years Canadian mines have made great advances in the field of noise abatement. Measurements have been taken to protect the miners' hearing and this procedure will be completely automated and connected into a computer system.

The new generation of noise dosimeters contributes to the solution of the following problems.

a) workers' safety

b) workers' health

c) environmental impact, and

d) productivity.

The system exemplifies the important role of the computer program based on the total computations of shift time (8 h = 480 min) averaging every one minute L_{OSHA}. Full information can be obtained; time history (numerical), site code, job code, user code, number of computations (time), L_{OSHA} (current and cumulative), percent dose (current and cumulative), minimum computations, maximum computations, arithmetic mean, standard deviation, variance, amplitude distribution (numerical and graphical) and time history (graphical).

One major contribution of this research is a demonstration of the collection of more pertinent noise data with the second generation noise dosimeter. Measurements will be greatly simplified if the new generation of noise dosimeters is built into the hat.

---

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INTRODUCTION

In the last ten years Canadian mines have made great advances in the field of noise abatement. Measurements have been taken to protect the miners' hearing and this procedure will be completely automated and connected into a computer system. The system with the new generation of noise dosimeters exemplifies the important role of the computer program based on the total computations of shift time (8 h = 480 min) averaging every one minute L_{OSHA}. Full information can be obtained; time history (numerical), number of computations (time), L_{OSHA} (current and cumulative), percent dose (current and cumulative), minimum computations, maximum computations, arithmetic mean, standard deviation, variance, amplitude distribution (numerical and graphical) and time history (graphical).

DEFINITIONS OF NOISE EXPOSURE INDEX AND EQUIVALENT CONTINUOUS SOUND LEVEL

The simplest measuring problem occurs when the sound level is constant, then the equivalent continuous sound level (L_{eq}) is equal to the reading of a sound level meter. When the sound level is not constant, the direct indication of L_{eq} requires a specialized instrument. In this case the noise exposure index (NEI) may be specified as being the constant sound level for the time duration.

The noise exposure has led to two standards and recommendations in North America. Among these are:

1) OSHA*; Walsh-Healey Act (USA federal law concerning hearing conservation in government supplying industry) used in all North America.
2) ISO**; Recommendation R 1999: Assessment of occupational noise exposure for hearing conservation purposes, used only in British Columbia, Canada.

---

* The Occupational Safety and Health Act (USA).
** The International Standards Organization.

Safe limits for noise exposure are often referred to as hearing conservation criteria.

INSTRUMENTS

All noise dosimeter manufacturers made an effort to have their instruments meet existing regulations and to give the final result: noise exposure index (NEI); Metrosonics Inc. started in the opposite direction. They constructed an instrument (actually a simplified dosimeter) that gives results which when combined make it easy to calculate the NEI through the numerical or graphical method.

306 METROLOGGER

The 306 Metrologger digital sound level analyzer is a pocket-size computer designed for automatic sound level analysis over a selected 64 dB range. The internal computer circuit samples the amplitude, calculates and provides 4 digit displays of SPL, L_{max}, L_{eq} or L_{OSHA}, and the time duration of the sampling period. The samples are converted to digital format and stored. The 306 analyzer samples the detected amplitude level 4 times per second. Test duration can be from one second to 252,750 seconds or 70.2 hours 252,750.25 x 4 = 1,011,001). The PROM (Program Modules) replacement feature provides the ability to change the functions of the 306 Metrologger.

301/651 METROLOGGING SYSTEM

The 301 Metrologger is designed for processing and storing sound level information. The 651 Metroreader is a desk analyzer with an internal printer. The 651 reader interrogates the 301's memories (similar to 306 Metrologger) and calculates important noise data, including time history profiles, amplitude distribution, histograms, computations of L_{eq}, L_{OSHA}, exposure coefficient criteria, etc. A variety of PROM (Program Modules) in the program library make the Metrologger multi-functional.

THE ACCURACY OF INSTRUMENTS

The accuracy of noise dose measured with dosimeters complying with ANSI Standard S1.25-1978 has been questioned because of the presence of impulsive wave forms (1). The errors are to be expected since dosimeters have limited crest factor capabilities. The averaging of SPL with a 3 dB exchange (trading) ratio is dependent on the wave form and the averaging time. J.J. Earshen has shown that (1):

> "Dosimeters complying with ANSI S1.25 and using 5 dB exchange ratio are intrinsically susceptible to noise dose overestimation in the presence of impulsive noise ..... In the final analysis, specialists who formulate hearing damage risk criteria must be fully appraised of instrument measurement capabilities and idiosyncrasies of proposed dosimeter standards."

G. Rasmussen disagrees and believes that the construction of dosimeters with a 3 dB exchange ratio is necessary (2). The data obtained can be mathematically or electronically converted to 5 dB exchange ratio values. The 301/651 Metrologging system is ideal for bringing this into reality. A computer program can convert noise measured with PROM for 3 dB exchange ratio to values of 5 dB exchange ratio (OSHA). The value of the results would be even greater since they enable specialists who formulate hearing damage risk criteria to evaluate both standards. Error with 3 dB exchange ratio would very likely be small.

It must again be stressed that it is possible to mathematically and electronically convert ISO values (3 dB exchange ratio to OSHA values of 5 dB exchange ratio). The converse is not possible either mathematically or electronically.

The 301/651 Metrologging system is a significant advance in noise monitoring instrumentation. Proposed systems go so far as to enable a computer to write a technical printout with all necessary results.

THE NOISE DOSIMETER SURVEY

The aims of the noise exposure index measurements are outlined in Fig. 1 under two general headings:

1) partial information of NEI measurement for the worker, union and safety office; and
2) full information of NEI measurement for management, union and environmental office directly and for government agencies and compensation board indirectly.

The system of measurement has a two-fold purpose:

1) to protect the hearing of the worker; and
2) to increase productivity.

PARTIAL INFORMATION

At the beginning of the shift the 301 Metrologger (noise dosimeter) was given to the worker. The microphone was clamped onto the rim of the hat or on the collar. The noise survey form was filled in with pertinent information on the worker: name, payroll number, occupation, location, etc. After the shift the 301 Metrologger is connected to a 651 Metroreader which provides the first hard copy of current and cumulative L_{OSHA} results. The following day the worker, in this case driller, B. Leyte, receives the information. On the basis of this information he can evaluate the necessity of personal protection, and discuss this with co-workers and the union (Fig. 2). The safety office can supply the necessary equipment and give advice on hearing protection.

FULL INFORMATION

The Metroreader was connected by the interface to the Facit tape punch machine or directly input to the computer depending on needs and circumstances. Based on the total computations of shift time (8 h = 480 min) averaging every

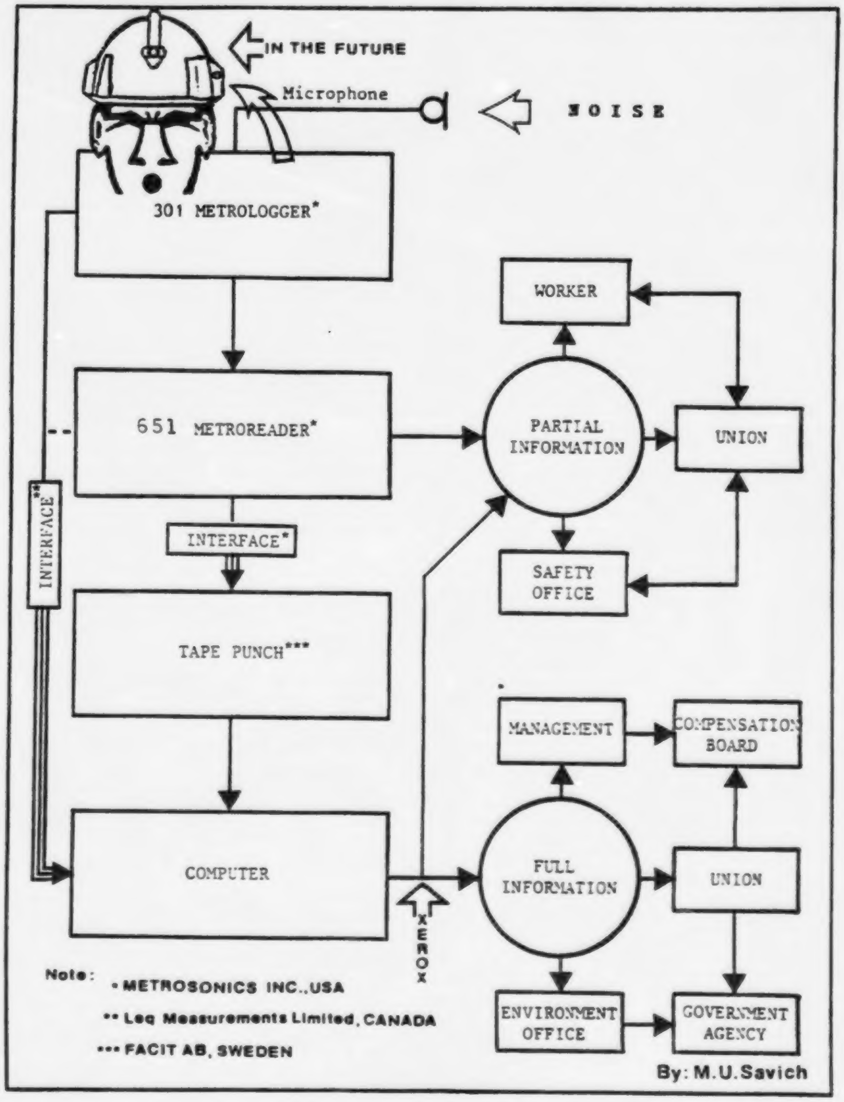
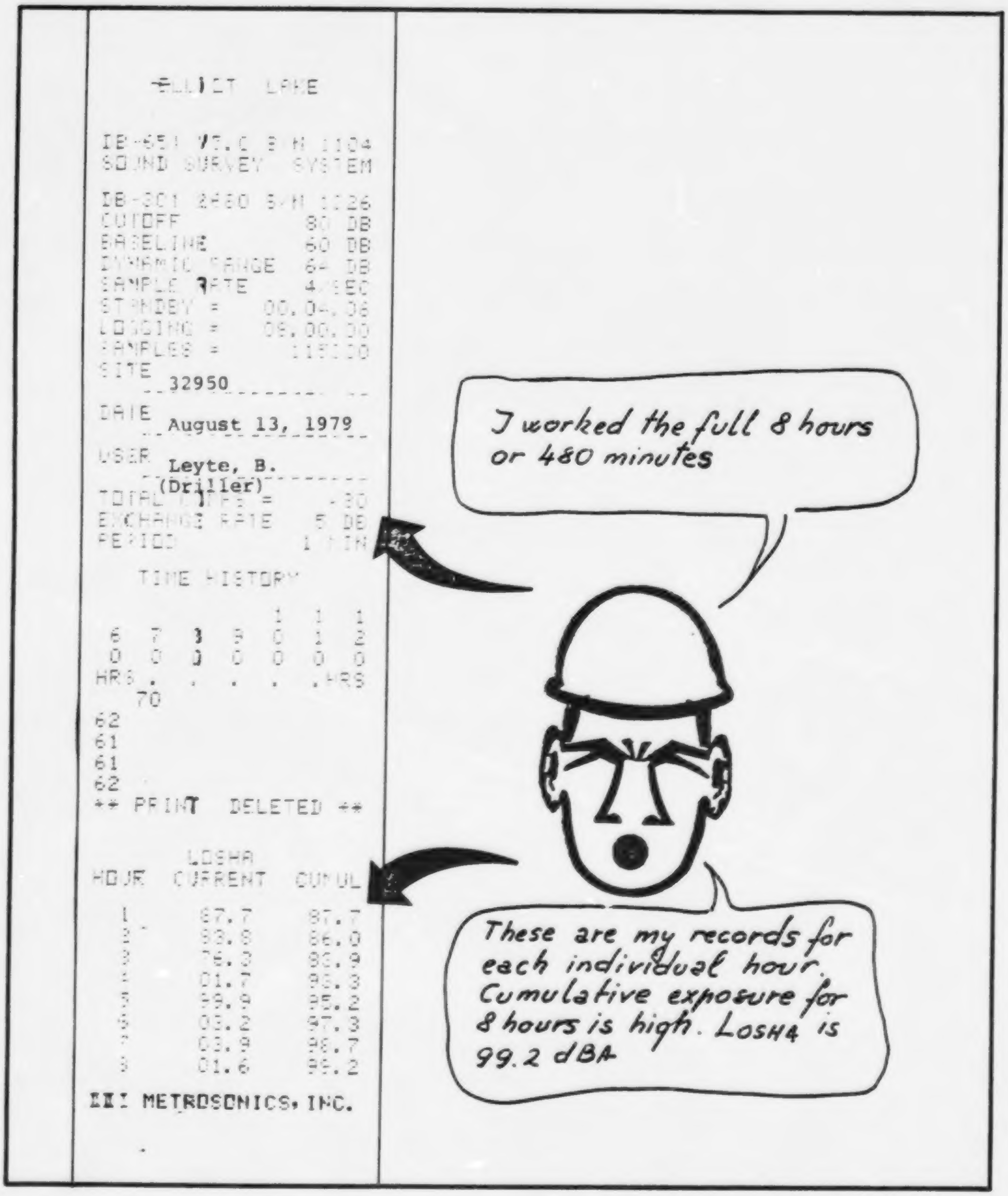

IN THE FUTURE
Microphone
NOISE
301 METROLOGGER*
651 METROREADER*
INTERFACE**
INTERFACE*
TAPE PUNCH***
COMPUTER
XEROX
WORKER
PARTIAL INFORMATION
UNION
SAFETY OFFICE
MANAGEMENT
COMPENSATION BOARD
FULL INFORMATION
UNION
ENVIRONMENT OFFICE
GOVERNMENT AGENCY
Note:
* METROSONICS INC., USA
** Leq Measurements Limited, CANADA
*** FACIT AB, SWEDEN
By: M.U.Savich

Fig. 1: Flow sheet diagram of Noise Exposure Index test procedure.



```
     ELLIOT  LAKE

DB-651 V3.0 S/N 1104
SOUND SURVEY  SYSTEM

DB-301 2480 S/N 1226
CUTOFF           80 DB
BASELINE         60 DB
DYNAMIC RANGE    64 DB
SAMPLE RATE      4/SEC
STANDBY =     00.04.06
LOGGING =     08.00.00
SAMPLES =       115200
SITE
  32950
DATE
  August 13, 1979
USER
  Leyte, B.
  (Driller)
TOTAL [illegible] =     480
EXCHANGE RATE     5 DB
PERIOD            1 MIN

    TIME HISTORY

                1  1  1
 6  7  8  9  0  1  2
 0  0  0  0  0  0  0
HRS .  .  .  .  . HRS
   70
62
61
61
62
** PRINT  DELETED **

         LOSHA
HOUR  CURRENT   CUMUL

  1     87.7     87.7
  2     93.8     86.0
  3     76.3     90.9
  4     01.7     95.3
  5     99.9     95.2
  6     03.2     97.3
  7     03.9     98.7
  8     01.6     99.2

III METROSONICS, INC.
```

I worked the full 8 hours or 480 minutes
These are my records for each individual hour. Cumulative exposure for 8 hours is high. LOSHA is 99.2 dBA

Fig. 2: Partial information on the noise dosimeter survey: L_{OSHA} (current and cumulative).

one minute L_{OSHA} and on the computer program, full information can be obtained (Fig. 3 and 4): time history (numerical); site code, job code, user code, number of computations (time), L_{OSHA} (current and cumulative) percent dose (current and cumulative), minimum computations, maximum computations, arithmetic mean, standard deviation, variance, amplitude distribution (numerical and graphical) and time history (graphical).

The environmental office has all the necessary data to enable it to set guide lines, and in cooperation with the union, can reach correct and acceptable conclusions. The union has an opportunity to examine all problems very closely. Management and the union have a hard copy from which they can conclude whether or not the claimant is justified in going to the Workmen's Compensation Board. On the basis of these measurements correct and acceptable conclusions are possible.

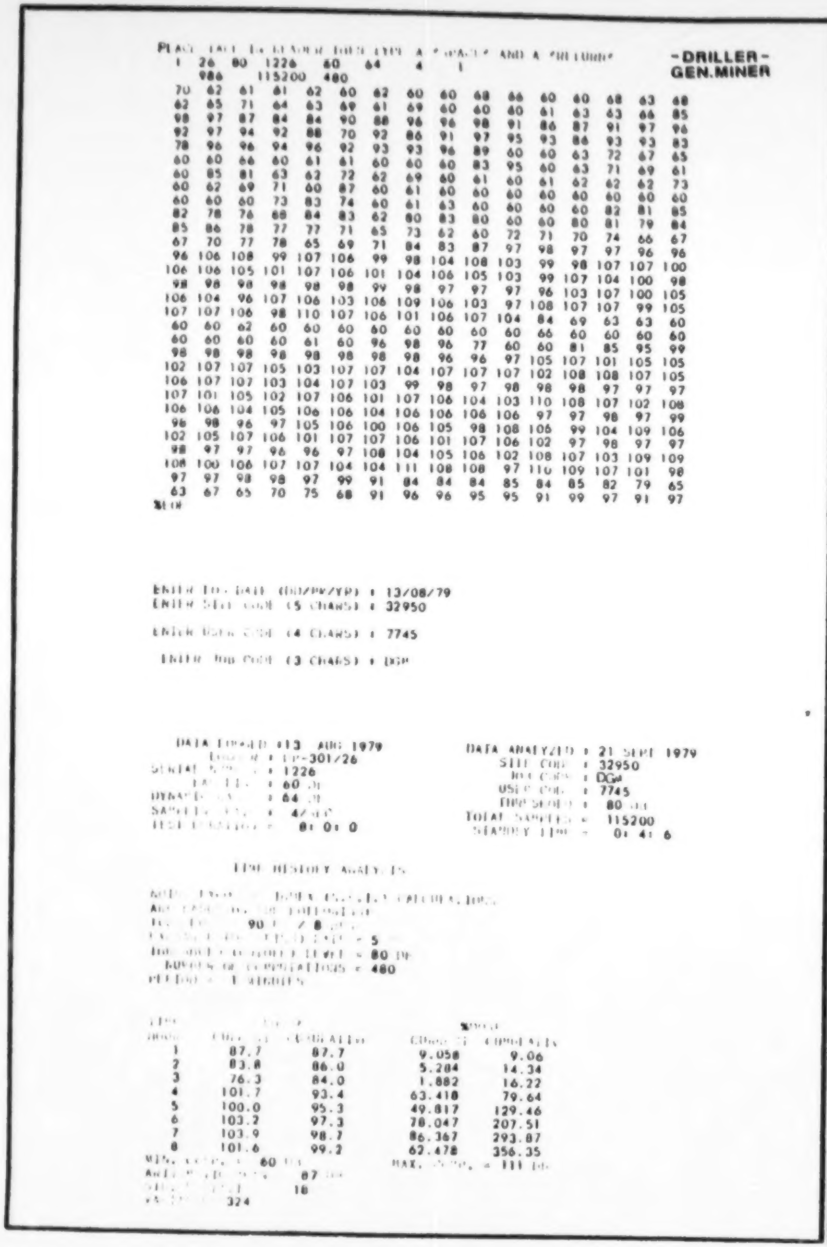
The productivity trend in the last half of the decade was likely the same.

Because Canada's share of the world market has declined, we must first increase productivity in present mines. Full information of noise exposure measurements can help in this effort (Fig. 4).

The environmental office takes on the role of an operative unit and loses its bureaucratic character.

CONCLUSIONS AND RECOMMENDATIONS

Special attention is commanded by two extreme conditions, usually referred to as "safety" and "productivity". The model provides a reasonable explanation and full information of NEI, but generally these should be used by workers, the union, the safety and environmental offices and the management in order to provide a safe working environment with increase in productivity. This method of measurement was performed for the first time ever at local mines in



```
PLACE TAPE IN READER THEN TYPE A "SPACE" AND A "RETURN"              -DRILLER-
  1   26   80   1226    60    64     4     1                          GEN.MINER
     986       115200  480
  70   62   61   61   62   60   62   60   60   68   66   60   60   68   63   68
  62   65   71   64   63   69   61   69   60   60   60   61   63   63   66   85
  98   97   87   84   84   90   88   96   96   98   91   86   87   91   97   96
  92   97   94   92   88   70   92   86   91   97   95   93   86   93   93   83
  78   96   96   94   96   92   93   93   96   89   60   60   63   72   67   65
  60   60   66   60   61   61   60   60   60   83   95   60   63   71   69   61
  60   85   81   63   62   72   62   69   60   61   60   61   62   62   62   73
  60   62   69   71   60   87   60   61   60   60   60   60   60   60   60   60
  60   60   60   73   83   74   60   61   63   60   60   60   60   82   81   85
  82   78   76   88   84   83   62   80   83   80   60   60   80   81   79   84
  85   86   78   77   77   71   65   73   62   60   72   71   70   74   66   67
  67   70   77   78   65   69   71   84   83   87   97   98   97   97   96   96
  96  106  108   99  107  106   99   98  104  108  103   99   98  107  107  100
 106  106  105  101  107  106  101  104  106  105  103   99  107  104  100   98
  98   98   98   98   98   98   99   98   97   97   97   96  103  107  100  105
 106  104   96  107  106  103  106  109  106  103   97  108  107  107   99  105
 107  107  106   98  110  107  106  101  106  107  104   84   69   63   63   60
  60   60   62   60   60   60   60   60   60   60   60   66   60   60   60   60
  60   60   60   60   61   60   96   98   96   77   60   60   81   85   95   99
  98   98   98   98   98   98   98   98   96   96   97  105  107  101  105  105
 102  107  107  105  103  107  107  104  107  107  107  102  108  108  107  105
 106  107  107  103  104  107  103   99   98   97   98   98   98   97   97   97
 107  101  105  102  107  106  101  107  106  104  103  110  108  107  102  108
 106  106  104  105  106  106  104  106  106  106  106   97   97   98   97   99
  96   98   96   97  105  106  100  106  105   98  108  106   99  104  109  106
 102  105  107  106  101  107  107  106  101  107  106  102   97   98   97   97
  98   97   97   96   96   97  108  104  105  106  102  108  107  103  109  109
 108  100  106  107  107  104  104  111  108  108   97  110  109  107  101   98
  97   97   98   98   97   99   91   84   84   84   85   84   85   82   79   65
  63   67   65   70   75   68   91   96   96   95   95   91   99   97   91   97
%EOF


ENTER TO-DATE (DD/MM/YR) : 13/08/79
ENTER SITE CODE (5 CHARS) : 32950

ENTER USER CODE (4 CHARS) : 7745

 ENTER JOB CODE (3 CHARS) : DGM



   DATA LOGGED :13  AUG 1979                 DATA ANALYZED : 21 SEPT 1979
        LOGGER # : LP-301/26                      SITE CODE : 32950
SERIAL NUMBER : 1226                              JOB CODE : DGM
     [illegible] : 60 DB                          USER CODE : 7745
DYNAMIC RANGE : 64 DB                        THRESHOLD : 80 DB
SAMPLE [illegible] : 4/SEC                 TOTAL SAMPLES = 115200
TEST DURATION =   8: 0: 0                    STANDBY TIME =  0: 41: 6

          TIME HISTORY ANALYSIS

[illegible]
[illegible]
[illegible]      90 [illegible] / 8 [illegible]
[illegible] = 5 [illegible]
[illegible] LEVEL = 80 DB
  NUMBER OF COMPUTATIONS = 480
PERIOD = 1 MINUTES

TIME          [illegible]                         %DOSE
HOUR    [illegible]   CUMULATIVE          [illegible]   CUMULATIVE
   1       87.7        87.7               9.058       9.06
   2       83.8        86.0               5.284      14.34
   3       76.3        84.0               1.882      16.22
   4      101.7        93.4              63.418      79.64
   5      100.0        95.3              49.817     129.46
   6      103.2        97.3              78.047     207.51
   7      103.9        98.7              86.367     293.87
   8      101.6        99.2              62.478     356.35
MIN. [illegible] = 60 DB                  MAX. [illegible] = 111 DB
[illegible]           87 DB
[illegible]          18
[illegible]   324
```

FREQUENCY DISTRIBUTION

FREQUENCY		RANGE
NUMBER	PER CENT	
101	21.0	60 TO 64
26	5.4	65 TO 69
19	4.0	70 TO 74
12	2.5	75 TO 79
26	5.4	80 TO 84
19	4.0	85 TO 89
19	4.0	90 TO 94
106	22.1	95 TO 99
45	9.4	100 TO 104
103	21.5	105 TO 109
4	.8	110 TO 114
0	0.0	115 TO 119

TOTAL NO. OF DATA POINTS = 480

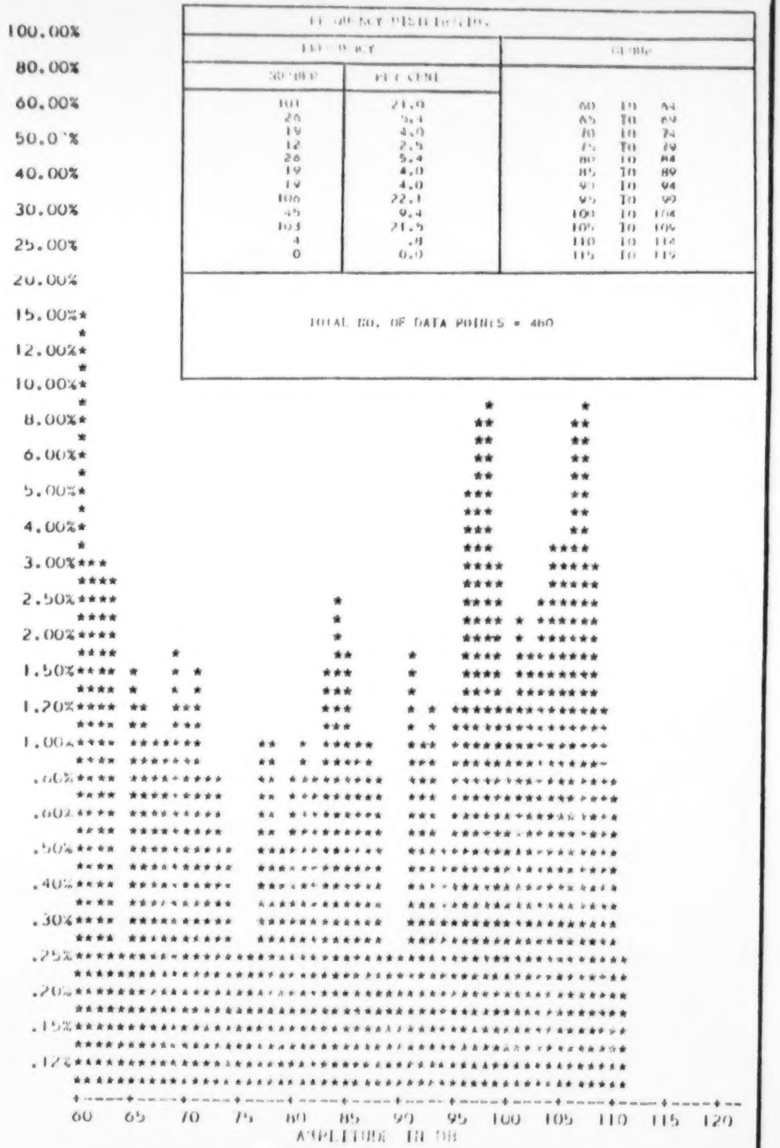


Fig. 3: Miners' full information of the noise dosimeter survey (basic data) and amplitude distribution (numerical and graphical).

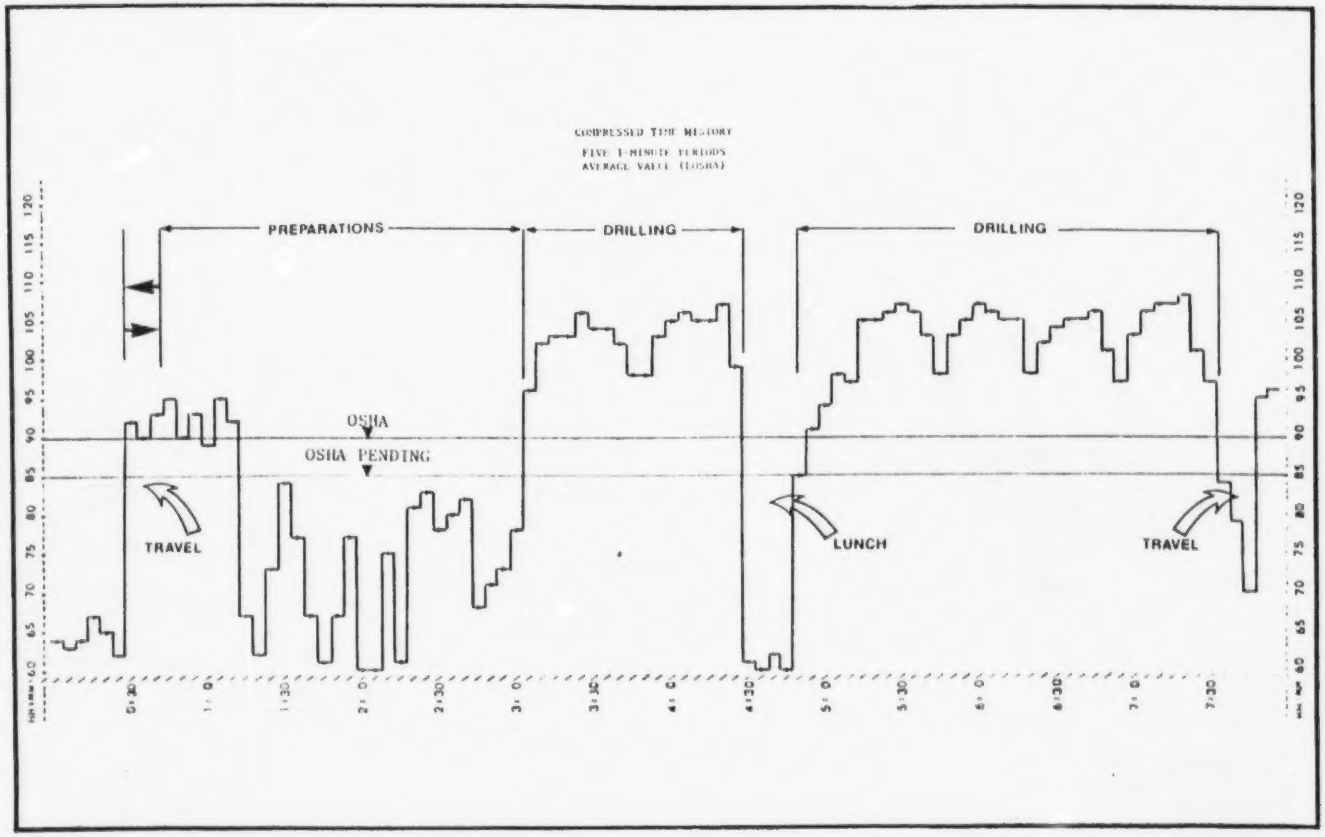


Fig. 4: Miners' full information of the time history (graphical).

cooperation with the Elliot Lake Laboratory.

One major contribution of this research is a demonstration of collection of more pertinent noise data with the second generation noise dosimeter. Measurement will be greatly simplified if the 301 Metrologger is built into the hat (Fig. 1) (3,4).

This method exemplified the important role of the computer program. In the future a program should be designed for retaining criteria (step 3 dB to 5 dB). This system of measurement contributes to the solution of the following problems:

1) workers' safety
2) workers' health
3) environmental impact
4) productivity

The management will have great use for this, since they will be able to follow up on work efficiency, maintenance and production. Also, the closer cooperation between workers management is important in order to have beneficial economic and social repercussions (5).

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New generation of noise dosimeters

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HOW CANMET TESTS NOISE POLLUTION

by

M. Savich*

ABSTRACT

Noise exposure measurements were performed in a uranium mine to determine future prospects for hearing conservation. OSHA requirements were used as a guideline for the regulation of noise emission. Noise exposure index measurements (NEI) were carried out for a full shift, and on the basis of the work cycle. Attenuation of ear muffs used in the mine was examined. CANMET's methods were applied during these measurements. These methods are simple, they do not require an increase in manpower and the principle of providing full information of results to workers is immediate.

Measurement results show that 61% of the workers are exposed to noise levels of 90 to 118 dBA (present OSHA), 78% are exposed to noise levels of 85 to 118 dBA (OSHA pending). This shows that management should adopt timely measures.

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L'ÉTUDE DE LA POLLUTION PAR LE BRUIT AU CANMET

par

M. Savich*

RÉSUMÉ

On a mesuré le niveau d'exposition au bruit dans une mine d'uranium afin de déterminer des solutions à apporter pour la conservation de l'ouïe. On s'est servi des exigences de la LSST comme guide pour l'établissement de règles relatives au taux de bruit. On a utilisé des appareils d'indice d'exposition au bruit (IEB) pour la durée entière d'une période de relève, sur une base de travail cyclique. On a examiné l'atténuation du bruit produite par des cache-oreilles utilisés dans les mines. Les méthodes du CANMET ont été utilisées pour ces mesures; elles sont simples, ne requièrent aucune main-d'oeuvre additionnelle, et offrent des renseignements complets immédiatement aux travailleurs.

Les résultats de nos mesures ont démontré que 61% des travailleurs sont exposés à des niveaux de bruit variant entre 90 et 118 dBA (normes actuelles de la LSST), alors que 78% le sont à des niveaux de 85 à 118 dBA (normes en instances de la LSST). Ceci démontre que la gestion devrait adopter des mesures opportunes.

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INTRODUCTION

The objective of industrial noise control and hearing conservation programs is to protect employees from permanent hearing loss in the speech frequency range.

Noise measurement in a uranium mine near Elliot Lake, Ontario, is directed towards three objectives. First, it identifies the main underground job categories by noise exposure index (dosimetry). Second, it measures cyclical noise, as such noise is often the case in mines. The noise exposure index is extrapolated from a few machine cycles. The correlation of the last day's noise dose and cyclical measurement noise dose can be found. Third, it establishes the effectiveness of ear muffs used in mines.

The measurement of noise levels and noise exposure index (NEI) should be associated with a noise control problem in a mine and mill. CANMET's techniques and experiences were applied.

Peak noise measurements were perfomred with a GenRad 1565 sound level meter. For a miner's daily noise dose, the GenRad 1944-9707 noise exposure monitors were used. Four noise dose meters, Bruel and Kjaer type 4425, were used to measure exposure and to indicate when 115 dBA was exceeded. The "noise monitor gun" was specially adapted to survey many work stations a day. It has the advantage that measurements are supervised at all times.

For full-shift measurements of the NEI, six instruments were put at the disposal of CANMET. For cyclical measurements of the NEI one instrument was used.

NOISE EXPOSURE INDEX

The noise exposure index was measured during full shift and cycles (short measurement).

The NEI varies slightly with individual occupational categories. Drillers and their helpers are exposed to the highest noise levels. Of the noise levels in all occupations, 77.6 per cent exceeded 115 dBA. A grouping by equipment and operation of main noise sources has been included in Table 1.

According to contemporary Occupational Safety and Health Act (OSHA) standards for occupational noise exposure 61 per cent of the mining work force is jeopardized by noise. And according to arranged regulations (OSHA pending), that number will rise to 78 per cent.

This is a signal to take seriously the work in keeping down noise pollution and to 1) buy the most silent machines and 2) increase the efficiency of personal protection.

Earlier enforcement of a noise pollution program will yield higher profit.

CYCLICAL MEASUREMENT

The total of the day's noise dose can be extrapolated from just a few machine cycles. This permits many operations to be surveyed in a day. It also has the advantage of supervising measurements at all times.

Evaluation of full shift NEI is done very easily:

$$\frac{\text{TDU} \times \text{OSHA \% exposure}}{\text{Unit measured} \times 100}$$

where:

TDU is the total day units (data obtained from supervision personnel).

OSHA % exposure (read off the instrument).

Unit measured (information taken during the period of measuring).

Results obtained are noted in a nomogram from which is obtained three equivalent continuous sound level (L_{OSHA}) during a full shift or eight hours. The accuracy of the method is plus-or-minus 0.5 due to paper distortion.

Table 1 - Main causes of noise in a uranium mine, grouped according to equipment and operation

No.	Equipment	No. Samples	L_{eq} (dBA)		No.	Occupation	No. Samples	Operation	L_{eq} (dBA)	
			Mean	Std Dev					Mean	Std Dev
1	2-Boom Electric Jumbo	6	100.25	2.48	1	Jumbo Operator	4	Incline/Decline	99.43	2.22
2	3-Boom Electric Jumbo	4	99.5	3.42			5	Trackless Drift	100.70	3.38
3	ST-8 Scooptram	9	100.39	1.94	2	L.H.D. Operato	5	Incline/Decline	99.8	0.88
							4	Trackless Stope	101.13	2.77
4	Rockbolter	8	100.35	8.47	3	Rockbolter	5	Incline/Decline	102.90	8.24
							3	Trackless Stope	96.10	8.47
5	Jackleg-1	13	103.64	8.98	4	Driller	10	Raise	105.91	7.56
6	Jackleg-2	12	99.44	10.42			7	Drift	103.16	11.19
7	Jackleg-3	4	110.53	8			17	Stope	98.17	9.86
8	Stoper	5	94.38	9.63			1	Pillar Round	118	-
9	Wagon Drill	2	99.4	8.63						

Summary test data of noise origin is given in Table 2. By this test it was concluded that the driller is most exposed to noise, followed closely by the rockbolter.

From the cyclical measurements of the NEI, values are calculated of the equivalent continuous sound level (short time). The average noise level during real work is high, 105 dBA.

A short comparative analysis was carried-out between the two methods of measuring, full shift and cyclical (short). In jumbo operation, rockbolting and drilling, even though the number of measurements was small, the values are nearly equal for the two measuring methods. Cyclical measurement showed a value somewhat smaller by 1.24 dBA and 1.1 dBA. The average continuous equivalent noise level (L_{OSHA}) obtained on the basis of cyclical (short) measurement, had a mean of 99.77 dBA. The value is higher by 4.79 dBA than the one obtained during full shift noise dose measurements (95.58 dBA). The reason for such a large difference is the small number of measurements carried out at job locations with a lower noise level.

EAR MUFF ATTENUATION

A study was undertaken to measure ear muff attenuation in mines. A series of 14 ear muffs was tested under uniform conditions in the mine. No-Noise ear muffs are in common use in mines. MSA Mark IV and American Optical were experimentally comparable models.

The only certain means for evaluating the efficiency of the hearing protection program, equipment, training and supervision is to measure periodically the hearing threshold of all miners exposed to noise. This method does not detect problems until some hearing loss has occurred. Because of this, a new method was developed in CANMET's Elliot Lake laboratory to

Table 2 - Summary of cyclical measurements of the equivalent sound level and ear protection data

No.	Occupation	No. of Samples	L_{eqs} (dBA)			No. of Samples	Peak SPL (dBA)			Percent of Total				
			Range	Mean	St. Dev.		Range	Mean	St. Dev	Plugs	Muffs	Plugs & Muffs	Question-able	None
1	Jumbo Operator	12	89.2 to 111.5	106.16	5.84	10	106 to 116	111.5	4.06	75	25			
2	L.H.D. Operator	11	89.9 to 112	100.81	5.86	4	110 to 114	111.2	2	27.3	54.5		9.1	9.1
3	Rockbolter	5	105.7 to 112.4	109.26	2.59	5	113 to 117	115	1.87	80	20			
4	Driller	68	101 to 122	115.85	3.91	47	117 to 126	121.68	2.75	20.6	69	7.4		2.9
5	Mucking	41	80 to 119.5	97.78	6.56	27	96 to 115	106.4	7.26	34.1	65.9			
6	Haulagemen	16	94.2 to 110.5	101.83	5.2	17	100 to 123	112.47	8.52	89.5				10.5
7	Level Service	3	105.6 to 106	105.87	0.23	3	107 to 110	108	1.73		66.7		33.3	
8	Dia. Driller	7	80 to 104	98.5	8.33	6	105 to 109	107	2.19		85.7		14.3	
9	U/G Crusher	7	97.2 to 104.5	102.33	2.46	7	96 to 109	107.14	4.91	100				
10	Skip Tender	7	87.9 to 93.2	90.37	2.16	7	104 to 115	107	4.07	85.7			14.3	
11	General Travel*	10	80 to 92.6	85.43	5.64	2	98	98					100	
		187	←						Σ	38.9	48.4	2.6	7.4	2.6

*Surface

provide an assessment of attenuation efficiencies of ear muffs in mines.

Test data on ear muffs are given in Table 3. Brand new ear muffs were those labelled No. 1, No. 2, No. 4, No. 6 and No. 11. Ear muffs No. 1, MSA Mark IV, and No. 2, No-Noise, were worn by jumbo operators. Operators were requested to move their necks as little as possible. Attenuation in both cases was excellent. In other cases, during normal work, the attenuation varied considerably. Average attenuation for seven No-Noise ear muffs was approximately 12 dBA. The other new ear muffs also had similar low attenuation, ranging from 15 to 16 dBA.

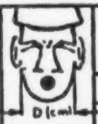
The efficacy of single number measurements of hearing protector noise reduction has been examined elsewhere by E.H. Berger. The accuracy of the estimate will be a function of both the computational procedure and the assumed attenuation data. Utilization of a long computational method gains one little in terms of improving estimates of the real protection received by industrial workers. Real attenuation results should be taken into account because the greatest noise reduction is not always given by ear muffs which have the best US Environmental Protection Agency reduction rating (see Fig. 1).

CONCLUSIONS

Measurement results show that the majority of underground workers, 61 per cent, are exposed to noise which varies from 90 to 118 dBA. The measurements also show that hearing protectors presently used in mines are inadequate when combatting noise existing there.

Noise exposure index measurements were done during full shifts and short cycles. The full shift NEI measurements have yet to serve in a suitable and required application. The cause is three-fold: 1) the impractical nature of wearing dosimeters; 2) damage to the microphone was frequent and

Table 3 - Attenuation of ear muffs at a uranium mine

No.	Occupation	Ear muff	Band	 D(cm)	Equivalent Continuous Sound Level - L_{eqa} (dBA)						Average Attenuation (dBA)	Remarks
					Left Muff			Right Muff				
					Over	Under	Diff.	Over	Under	Diff.		
1	3-Boom Jumbo	M.S.A. Mark IV		13.3	107.8	<80	>27.8	108.1	<80	>28.1	>27.95	
2	2-Boom Jumbo	No-Noise		14	107.2	<30	>27.2	106.6	<80	>26.6	>26.9	Environmental Sampler
3	2-Boom Jumbo	No-Noise		14				106.8	93.7	13.1	13.1	
4	2-Boom Jumbo	M.S.A. Mark IV		14				105	90	15	15	
5	Rock Bolter (Helper)	No-Noise		13.6	114.5	106.2	8.4	115.2	104.9	10,3	9.35	
6	Jackleg (Driller)	Amer. Optical		14.1	116	102.7	13.3	115.5	99.4	16.1	14.7	
7	Jackleg (Driller)	No-Noise		14.7	114.6	98.2	16.4	114.9	105	9.9	13.15	Long hair
8	Jackleg (Driller)	No-Noise		14	111.8	93.2	18.6	112.7	94.6	18.1	18.35	Ideal Condition
9	Jackleg (Helper)	No-Noise		13.8	112.6	108	4.6	114.3	98.8	15.5	10.05	Long hair
10	Slusherman	No-Noise		13.7	93.6	80.4	12.2	94.4	86.1	8.3	10.45	Lack spring pressure
11	Slusherman	Amer. Optical		13.9	95.1	<80	>15.1	95.3	85	15.3	~15.2	New muff
12	Slusherman	No-Noise		14	96.8	<80	>16.8	97.5	<80	>17,5	>17.15	
13	JC800 Scooptram	No-Noise		14.2	102	89.5	12.5	101	91.4	9.6	11.05	New Liner
14	ST8 Scooptram	No-Noise		13.3	101.7	91.6	10.1	101.5	89.8	11.7	10.9	
	Mean			13.9			11.83*			11.91*	11.9*	
	Std. Dev.			0.36			4.73			3.56	3.08	

*"No-Noise" Nos. 5,7,8,9,10,13 and 14 ear muffs.

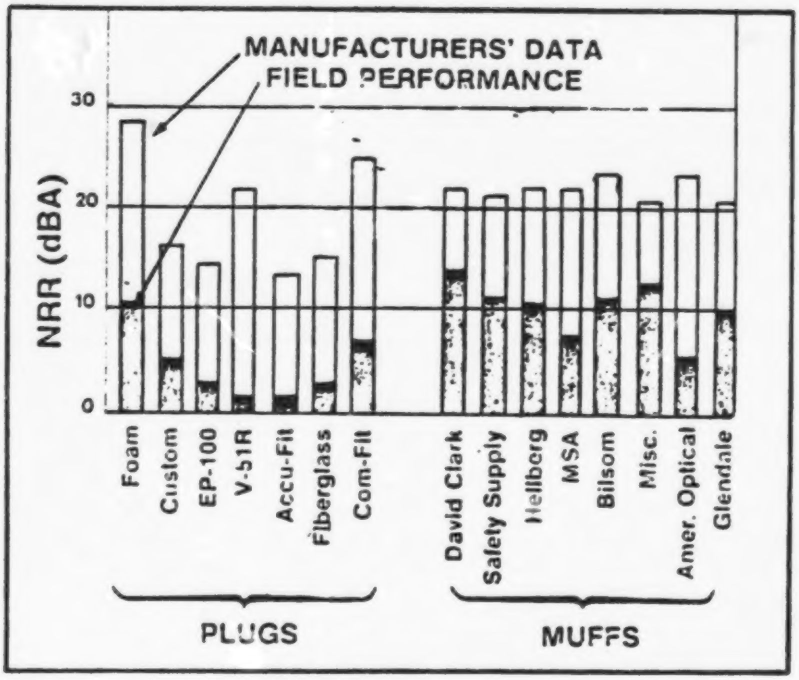


Fig. 1: Field performance and manufacturers' data of hearing protectors measured against US EPA noise reduction ratios (NRR). After Berger.

some dosimeters were lost altogether; and 3) instrument prices are forbidding, so much so that management has balked at making permanent measurements as required.

Because of this, cyclical measurements are better and simpler for small mines and mills. In this case many work stations are surveyed in a day and there is the advantage of supervised measurements with results immediately evaluated. The results are immediately reported to the worker, either verbally or in writing. This, hopefully, influences the worker to consider protecting himself immediately.

A flow diagram can be constructed for small and medium sized mines to improve noise control (see Fig. 2). It should be finalized through modification and adaptation by the management.

The following is recommended:

1) Full shift noise dose measurements should be done only in places of no cyclical work, mainly work places where there is less noise;
2) Short cyclical measurements should be applied in other places and the results should be immediately evaluated using the graphical method;
3) For evaluating the efficiency of ear muffs, CANMET's noise monitor vest with two dosimeters should be used. Clamping force measurements should become mandatory. On the basis of distances between ears (bizygomatic diameter), a scale of minimum and maximum values for clamping force should be worked out without compromising comfort;
4) A spectral analysis of all machines in the mine and work places should be carried out. Compare measurement results with audiometric tests and characteristics of ear protection equipment. This study will show at what frequencies and why miners lose their hearing;
5) Because of maintenance, each machine introduced to the mine should be

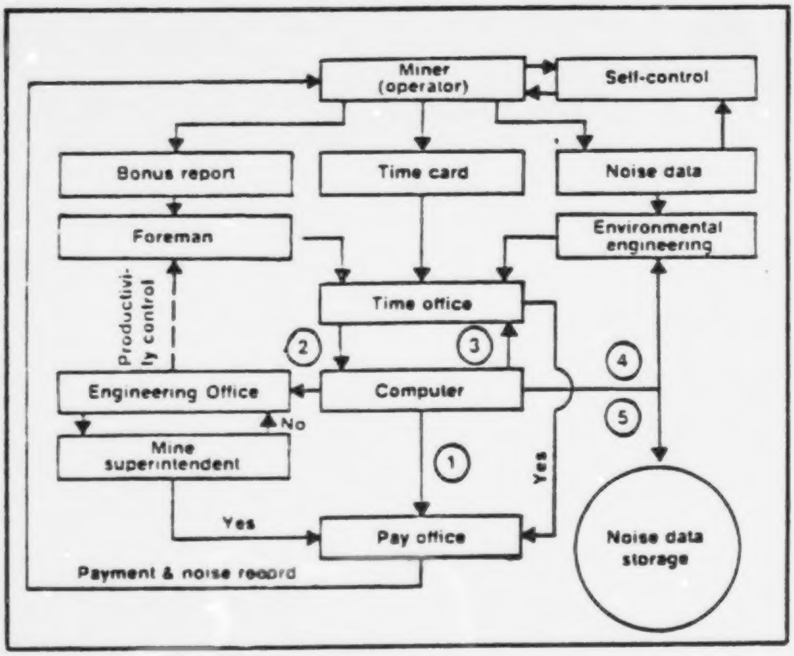

Miner (operator)
Self-control
Bonus report
Time card
Noise data
Foreman
Environmental engineering
Time office
Productivi-ty control
2
3
4
Engineering Office
Computer
No
5
Mine superintendent
1
Yes
Yes
Pay office
Noise data storage
Payment & noise record

Fig. 2: Cross-payment flow diagram for improving noise environmental control. 1) To the pay office. 2) To the engineering office (final control). 3) To the time office (final control). 4) To environmental engineering. 6) To storage.

measured for L_{OSHA} and SPL peaks;

6) At any work place where the L_{OSHA} exceeds 102 dBA (according to today's use of ear muffs), it should become mandatory for workers to wear both ear muffs and ear plugs.

The methods used by CANMET are simple. They do not require an increase in manpower and they can be used constructively for noise abatement in mines. The method is so simplified that a surveyor could conceivably learn the noise measurements and evaluations in a few hours. Tests have demonstrated that only mine employees can perform these measurements efficiently.